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The Coffee Shop Effect: Investigating the Relationship between Ambient Noise and Cognitive Flexibility

Emily G. Nielsen

The University of Western Ontario

Supervisor

Dr. John Paul Minda

The University of Western Ontario

Graduate Program in Psychology

A thesis submitted in partial fulfillment of the requirements for the degree in Master of Science

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THE COFFEE SHOP EFFECT:
INVESTIGATING THE RELATIONSHIP BETWEEN AMBIENT NOISE AND
COGNITIVE FLEXIBILITY

(Thesis format: Monograph)

by

Emily Grace Nielsen

Graduate Program in Psychology

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science

The School of Graduate and Postdoctoral Studies
The University of Western Ontario
London, Ontario, Canada

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Abstract

Cognitive flexibility is the ability to think diversely in order to solve problems and learn concepts. It has also been suggested that cognitive flexibility supports creativity. Research has demonstrated that creativity is enhanced by moderate volumes of ambient noise. This thesis sought to replicate and extend this line of research by investigating how noise affects cognitive flexibility. Study 1 assessed the effects of noise on three creativity tasks. Performance was found to be enhanced by ambient noise, particularly among those who listen to music while they study/work. Study 2 examined how noise affects performance on a category learning task designed to measure cognitive flexibility. Category learning was neither enhanced nor impaired by ambient noise. This work suggests that noise may be beneficial for creativity but not for learning. Further research is needed to clarify the effect that ambient noise has on cognitive flexibility as it applies to other, non-learning-based tasks.

Keywords

Ambient Noise, Creativity, Cognitive Flexibility, Category Learning, Individual Differences, Divergent Thinking, Convergent Thinking, Rule-Based Categorization, Information Integration Categorization, COVIS Theory.

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List of Abbreviations

ADHD	Attention Deficit/Hyperactivity Disorder
AIC	Akaike Information Criterion
ANOVA	Analysis of Variance
ATTA	Abbreviated Torrance Test for Adults
AUT	Alternate Uses Task
BIF	Behavior Identification Form
COVIS	COmpetition between Verbal and Implicit Systems
CRA	Compound Remote Associates
GRT	General Recognition Theory
II	Information Integration
PANAS	Positive and Negative Affect Schedule
RAT	Remote Associates Test
RD	Rule-Defined

Chapter 1

1 The Coffee Shop Effect

In recent years, coffee shops seem to have become synonymous with office space, with laptops now seemingly as commonplace as coffee cups. It is not uncommon, in a typical shop, to come across at least a few customers who appear to be there primarily to work as opposed to drink coffee. In fact, the year 2014 saw a 3% decrease in the number of coffees purchased by Canadians; the number of visits to coffee shops, however, remained the same (NPD Group, as cited by Canadian Broadcasting Corporation [CBC] News, 2015). There must be something other than the availability of caffeinated beverages, therefore, that makes a coffee shop a welcoming work environment.

For some individuals, the draw may be in the change of scenery that a coffee shop provides, relative to their typical work environments. The informal atmosphere of a coffee shop may offer a welcome escape from the confines of a traditional office, and the resulting sense of relaxation may be helpful for stimulating the flow of ideas. A creative writer, for instance, could draw inspiration from the various people they see and conversations they overhear while working in a café. Compared to an office, coffee shops have the added benefit of allowing an individual to work in the company of others without the temptation to chat with co-workers. Consequently, someone who benefits from working on their own, but does not enjoy isolation, may find that they are particularly productive in coffee shops, which provide the experience of being in public without the obligation to engage others in conversation.

This feeling of being out in public is facilitated by a key aspect of the coffee shop environment: ambient noise. Other features of a coffee shop, such as the tables, chairs, coffee, and snacks, are similar to what one could find at home or in an office. The sounds of conversations, cups, and cutlery, however, make it apparent that there are other people nearby, even to those who may be focused predominantly on a computer screen.

1.1 Ambient Noise

Regardless of whether others are present or not, noise is unavoidable. Even in Orfield Labs' anechoic chamber, which boasts the title of quietest place on Earth, absolute silence is impossible to achieve. In the chamber, individuals report hearing their own heartbeat, lungs, and other bodily organs; this experience is very disorienting and, for some, even induces hallucinations (Thornhill, 2012). Clearly, therefore, a complete lack of noise is not idyllic and, in fact, quietness in day to day life is rare.

Many environments are regularly punctuated with loud and diverse sounds. Consider, for instance, the noises which typically accompany a morning commute to work: car engines, music, conversations, and horns, all come together to form an ambient atmosphere which can be quite distracting. Despite the chaos, the majority of drivers manage to arrive safely at their destination, presumably because they are able to ignore the noise and focus on the task at hand. In other environments, such as hospital operating rooms, this may be more difficult to do, particularly for individuals who are unfamiliar with such a place. It is imperative, however, that doctors and nurses overcome any noise-induced distractions to think coherently and perform their jobs.

Different types and volumes of noise may, thus, have a variety of effects on cognition; in some cases it may be successfully ignored, while in others it may be sufficiently distracting that it impairs task performance. Still, in other instances, the absence of noise may be more unsettling than its presence. Consequently, it may be that some types of noise are beneficial to certain aspects of cognition; perhaps, it is the ambient noise that makes coffee shops enjoyable places in which to work. The goal of the present studies was to investigate this possibility by assessing how noise affects certain aspects of cognitive functioning.

1.2 Cognitive Flexibility

In particular, this thesis focused on cognitive flexibility, which refers to the ability of different aspects of cognition to operate flexibly in order to achieve a goal. This broad working definition has permitted the study of cognitive flexibility in a number of

different research contexts. As Ionescu (2012) states, however, such broad definition has also led to inconsistencies in the way in which the term is conceptualized. For instance, some researchers view cognitive flexibility as a distinct entity while others view it as a characteristic of certain processes, such as language learning and the formation of mental representations (as discussed in Ionescu, 2012). Within the context of this thesis, cognitive flexibility is defined according to the Cognitive Flexibility Theory proposed by Spiro, Coulson, Feltovich, and Anderson (1988): as a feature of executive functioning that supports diverse thinking and problem solving.

Spiro et al. (1988) first conceptualized cognitive flexibility as a way to explain learning that occurs within ill-defined domains. In their work with biomedical students, the researchers identified mental rigidity as a key factor that undermined the students' ability to correctly grasp concepts. For knowledge acquisition to occur, Spiro et al. stated that learners must "attain a deeper understanding of content material, reason with it, and apply it flexibly in diverse contexts" (p. 4). To illustrate the roles that cognitive flexibility plays in learning, the following offers a rudimentary breakdown of how knowledge is acquired.

One way to simplify learning is to view it as a categorization task. The process begins with new knowledge being considered in conjunction with previously acquired knowledge. If the new knowledge shares a sufficient number of key features with a specific area of previous knowledge, it may be grouped according to that similarity. In this way, information regarding a domain may be gradually acquired and integrated to form a larger, more comprehensive knowledge base. Over time, domains may be reorganized as more information is gathered and a deeper understanding of the subject matter is achieved. (E.g. when children begin learning about animals, they may initially group cats and dogs together based on the similarity of their surface features. As they acquire more knowledge regarding animals, cats and dogs may become separate categories due to a shift in focus from surface to deep characteristics.) The ability to consider similarity beyond surface features, and amend categories based on new knowledge, requires flexible thinking. Flexibility is also important for applying this knowledge to solve problems in various contexts. By comparing a newly encountered problem with previous problems, potential solutions may be identified based on their

successful application in prior situations. Systematic testing may then occur until an appropriate solution is identified, switching from one to another as necessary.

Learning and problem solving, therefore, require a number of cognitive mechanisms: previous knowledge must be gathered from long term memory and brought into working memory; selective attention must bring key features into focus so that judgements of similarity may be made; conscious reasoning must occur to make decisions regarding information grouping and solution proposition; potential strategies must be planned and executed; switching behaviour must direct the hypothesis testing associated with solution evaluation; and any new information acquired from the problem solving process must be integrated into the appropriate mental representations of knowledge. Cognitive flexibility is also required for complex learning and problem solving, particularly in ill-defined domains, because it helps to: direct attention towards different features; group and re-group information as needed to make unusual, but necessary, connections between concepts; develop an inventory of potential solutions; transcend functional-fixedness to develop unique solutions; and overcome perseveration to switch responses when a solution is incorrect or inappropriate for the situation (Spiro et al., 1988).

1.3 Purpose of This Thesis

The research reviewed above suggests that cognitive flexibility is related to a number of cognitive functions, and it allows these mechanisms to work together to support diverse thinking, problem solving, and learning. Consequently, studying cognitive flexibility is useful for understanding the different factors that affect learning. Given its ubiquity, it would be valuable to know how sound affects learning and cognitive flexibility. In particular, it would be interesting to know if certain types of noise enhance or interfere with cognitive flexibility. Information such as this could be useful for designing work and school environments which are conducive to learning. Currently, little to no research exists in this area. The main purpose of this thesis, therefore, was to evaluate the relationship between ambient noise and cognitive flexibility.

1.4 Previous Research Regarding Noise

Although research regarding the effects of noise on cognitive flexibility is lacking, previous work has considered how noise interacts with other aspects of cognition.

1.4.1 Noise and Attention

One such aspect that has often been considered is attention. For instance, in a study involving children labeled by their teachers as either attentive or inattentive, Söderlund, Sikström, Loftesnes, and Sonuga-Barke (2010) demonstrated that white noise could improve attention in inattentive children. Participants were presented lists of 12 short sentences in random order, at a rate of one per 9 s. At the end of every list, participants were asked to verbally recall as many sentences as they could remember, regardless of order. White noise (78 dB) was presented concurrently with every other list. The results revealed that inattentive children achieved higher performance on lists presented during the noise condition than on lists presented without noise. Attentive children, in contrast, were found to be distracted by white noise, and performed best on the lists presented during the no noise condition.

Individuals with attention deficit/hyperactivity disorder (ADHD) are often unable to sustain prolonged attention due to the random firing of neurons caused by low levels of dopamine within the brain (Söderlund et al., 2010). According to the moderate brain arousal model (Sikström & Söderlund, 2007), the cognitive performance of a hypodopaminergic brain may be enhanced with stochastic resonance. Stochastic resonance refers to the addition of input “noise” within a system in order to increase the signal-to-noise output ratio. A hypodopaminergic brain could benefit from such a manipulation because it may allow for a distinction between random and task-related neural firing. For typical or hyperdopaminergic brains, however, the addition of input “noise” may overwhelm the system and cause a decline in task performance. Söderlund et al. (2010) suggested that the white noise implemented in their study was translated into neural noise as participants processed it. Stochastic resonance caused by this increased neural noise, in combination with differences in resting state dopamine levels, could explain why inattentive children benefited from the addition of white noise but attentive

children did not. Noise, therefore, seems to affect attention, although the effect appears to be moderated by individual differences.

In addition to having an effect on overall attention, noise appears to play a role in selective attention. In a study by Hockey (1970), for example, participants were asked to complete two tasks simultaneously. One task involved using their right hand to manipulate a handle and move a pointer across a display window. Also situated in this window was a target pointer which moved horizontally throughout the duration of the experiment. Participants were instructed to keep both pointers aligned with one another and were also told that this primary task was to be considered their main priority. As a secondary task, participants were asked to use their left hand to press corresponding keys when illumination of one of six lights on the table was detected. Over the course of one week, participants completed this task twice: once while in the presence of high volume (100 dB) white noise and once in the presence of low volume (70 dB) white noise.

Results from this study indicated that, for the high volume condition, tracking performance on the primary task was maintained throughout the duration of the study. In contrast, performance in the low volume condition gradually declined over time. Overall monitoring accuracy on the secondary task did not appear to benefit from high noise, although participants showed a narrowing of focus towards the centrally located lights during high volume, relative to the low volume condition. These results appear to suggest a role for high volume noise in selective attention: specifically, noise encourages an attentional bias towards primary tasks and a subsequent narrowing of attention towards secondary tasks (Hockey, 1970).

1.4.2 Noise and Arousal

A common explanation as to why such effects are observed with respect to noise and attention is that noise enhances arousal. Berlyne and Lewis (1963), for example, found that exposure to white noise (80 dB) led to an increase in galvanic skin response, relative to no noise. Results from behaviourally-based research also suggest that increased noise is related to increased arousal. For instance, sleep deprivation impairs performance on serial reaction tasks, but sleep deprived individuals, when presented with white noise (at

90 dB or 100 dB), have demonstrated faster reaction times (Corcoran, 1962) and fewer errors (Wilkinson, 1963). This suggests that noise may increase arousal to a normal, performance-supporting level, after having previously been depressed due to sleep deprivation. In these studies, it was also proposed that noise caused an increase in arousal for the non-sleep deprived participants; given that they began the task with normal levels of arousal though, this increased arousal was not beneficial and resulted in poor task performance.

1.4.3 Noise and Memory

Theories of memory and information processing, such as the three-component model of Baddeley and Hitch (as discussed by Baddeley, 2000), suggest that working memory is a limited resource. This means that the presence of new information, such as noise, can interfere with the processing of existing information held in working memory. In fact, both white noise and speech-based noise have been shown to impair working memory (Chein and Fiez, 2010).

Working memory processing is directly related to the storage of information in long term memory (Baddeley, 2000). Consequently, if noise impairs information processing in working memory, it should also have an effect on tasks which rely on long term memory. In a study designed to assess this possibility, Wais and Gazeley (2011) required participants to view images containing one, two, three, or four depictions of the same item. Participants were required to answer questions related, indirectly, to the size of the items presented in each image. Following a 60 min rest period, participants completed a surprise memory test in which they were shown names of items, and were asked to indicate how many of each item was present in the images shown during the earlier study session. During this testing phase, participants were either simultaneously exposed to white noise or noise recorded from a restaurant, or were asked to wear noise canceling headphones. As expected, performance on the recall test was worst for participants who listened to noise recorded from a restaurant. Interestingly, white noise did not impair recall and, instead, led to performance similar to that which was achieved by individuals who wore noise canceling headphones. Speech, due to its importance in human life, is attended to and processed automatically. As such, noise involving speech may be

particularly detrimental to task performance due to the demands it places on working memory; on the other hand, white noise may be relatively easy to block out. In fact, white noise has been shown to effectively act as a mask for speech-based noise, resulting in an improvement of performance on both simple and complex cognitive tasks (Loewen & Suedfeld, 1992).

1.4.4 Noise and Creativity

Many of the studies previously described in this section used manipulations involving white noise. White noise is a type of artificial noise that is created by combining all of the auditory frequencies which are detectable by the human ear. As discussed, however, white noise can have a markedly different effect on cognition than noise involving speech; in fact, white noise can be used as a mask for speech-based noise (Loewen & Suedfeld, 1992). It is important, therefore, for some research to implement more naturally occurring types of ambient noise.

A recent series of studies by Mehta, Zhu, and Cheema (2012), for instance, investigated the effects of conventional ambient noise on creativity. This work implemented a number of traditional creative thinking tasks, including the Remote Associates Test (RAT; Mednick, 1962), Brick Uses task (Wilson, Guilford, Christensen, & Lewis, 1954), idea generation task, and problem solving task (Burroughs & Mick, 2004). As they completed these tasks, participants were simultaneously exposed to pre-recorded noise which included sounds from a construction site, busy roadway, and a coffee shop. The noise, therefore, was a combination of both environmental sounds and incomprehensible speech. Participants were randomly assigned to a single volume condition, and the noise was presented at either 50 dB (low volume condition), 70 dB (moderate volume condition), or 85 dB (high volume condition). Across all tasks, performance was the best in the moderate volume condition. Based on these results, it was concluded that moderate volumes of ambient noise may enhance creativity, relative to both low and high volumes of noise.

As in previous research, arousal level, measured via heart rate and blood pressure, was found to be positively related to volume level. Over time, however, arousal level

stabilized, and the difference in arousal between the conditions became null. Performance on the tasks was found to be unaffected by time. Arousal was, therefore, dismissed as a significant mediating factor between noise volume and creativity. Instead, Mehta et al. (2012) hypothesized that the effect occurred indirectly through an increase in processing difficulty and abstraction. To assess this assumption, participants were asked to indicate their level of distraction, concentration, and comfort using a Likert scale, and complete the Behavior Identification Form (BIF; Vallacher, & Wegner, 1989). For each participant, the Likert scales were averaged to create an index of processing difficulty, and the BIF is a standard measure of construal level (i.e. cognitive abstraction). A multiple mediation analysis revealed that, compared to low noise, moderate volumes of ambient noise led to increased processing difficulty. Cognitive abstraction helped to overcome this difficulty, which subsequently led to enhanced creativity. When noise reached a certain level, however, information processing was reduced, which diminished the capacity for creative thinking. (Figure 1.1 provides a visual depiction of this proposed relationship between noise, processing difficulty, cognitive abstraction, and creativity.)

In the final study within the series, Mehta et al. (2012) sought to assess if this pathway between noise and creativity was affected by individual differences in baseline creativity. Participants in this study were presented with eight pairs of products. Each pair consisted of descriptions and images for both a traditional and a new, innovative product, both of which served the same purpose. Participants were asked to indicate, on a scale of one to seven, how likely they would be to purchase the new product as opposed to the traditional one. Participants were also asked to complete an innovativeness scale (Price & Ridgway, 1983) which assesses an individual's inclination to solve problems by using products creatively. Consistent with the other studies in their series, Mehta et al. (2012) found that willingness to buy an innovative product, as opposed to a traditional product, was positively related to an increase of ambient noise from low to moderate volume. They also found, however, that this relationship was moderated by scores on the innovativeness scale. Specifically, buying likelihood was found to be affected by volume for participants whose score on the innovativeness scale was equal to or greater than one standard deviation above the mean score; volume was not found to affect buying likelihood for participants whose score on the scale was equal to or less than one standard deviation

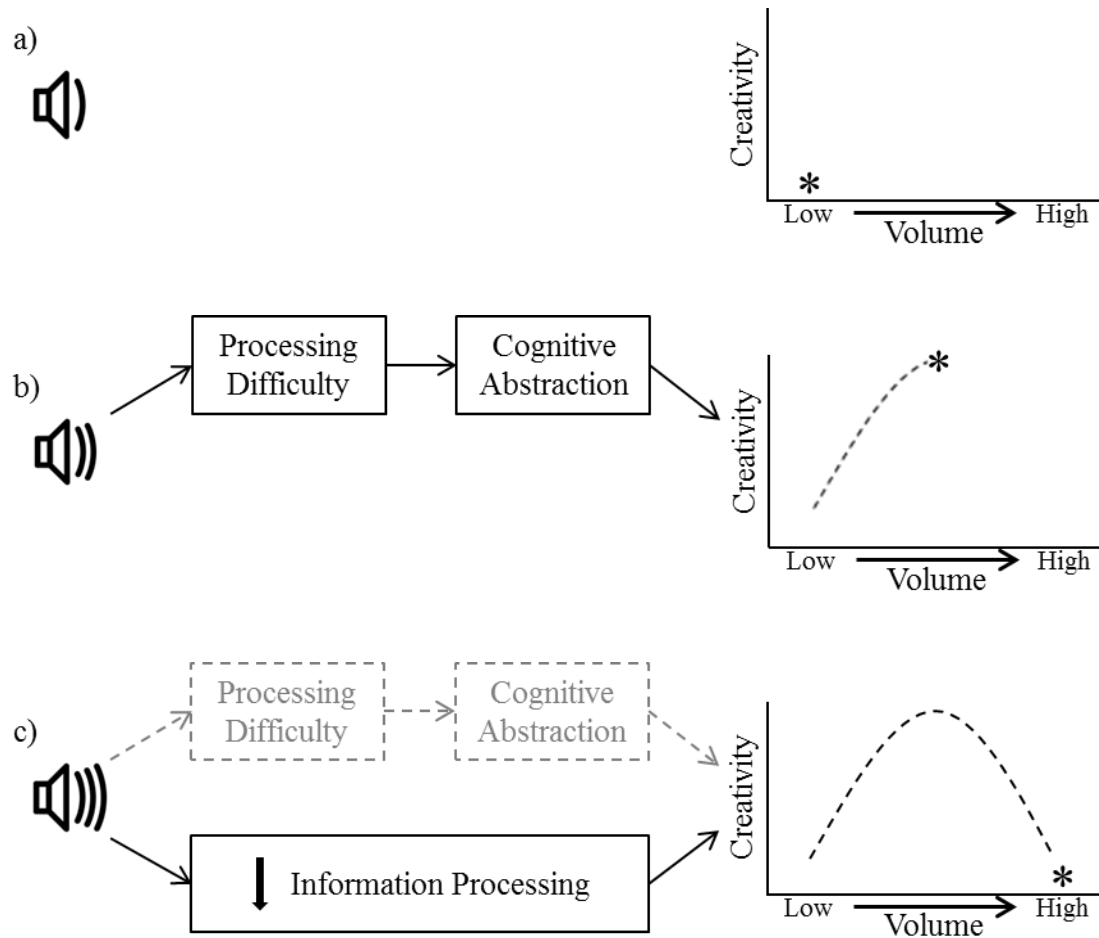


Figure 1.1. A depiction of Mehta et al.'s (2012) proposed relationship between noise and creativity. **a)** Under conditions of low noise, baseline creative performance is observed. **b)** When moderate volumes of noise are present, it becomes more difficult to complete the task at hand. Cognitive abstraction allows one to overcome this increased processing difficulty. Increased levels of cognitive abstraction, in turn, support a higher degree of creativity relative to baseline. **c)** When noise reaches a certain volume, the cognitive aspects involved in information processing are overwhelmed. The resulting decrease in processing that occurs effectively overrides the facilitative effects of increased cognitive abstraction, returning creative performance to baseline levels.

below the mean. Based on these findings, Mehta et al. suggested that moderate volumes of noise may only benefit creative performance for individuals who are naturally very creative. Similar to the relationship between noise and attention, therefore, the relationship between noise and creativity appears to be moderated by individual differences.

1.5 Creativity and Cognitive Flexibility

Clearly, there is a substantial body of research regarding the effects of noise on various aspects of cognition. Studies have shown differential performance on a number of cognitive tasks with respect to the type and volume of noise implemented. There is, however, a lack of research regarding the effects of noise on cognitive flexibility.

As previously discussed, cognitive flexibility is a feature of executive functioning that facilitates diverse thinking, problem solving, and learning (Spiro et al., 1988). According to the dual pathway to creativity model of Nijstad, De Dreu, Rietzschel, and Baas (2010), cognitive flexibility also contributes to the production of creative thought. In fact, this model contends that creativity is a direct function of cognitive flexibility and persistence. The flexibility pathway to creativity is defined as “the possibility of achieving creative insights, problem solutions, or ideas through the use of broad and inclusive cognitive categories, through flexible switching among categories, approaches, and sets, and through the use of remote (rather than close) associations” (p. 43). The existence of a flexibility pathway is supported by research demonstrating that flexibility is related to originality during idea generation (as discussed in Nijstad et al., 2010). A study conducted by De Dreu, Nijstad, and Baas (2011) also found that inducing flexibility via a scrambled sentence task led to a positive association between behavioural activation and creative performance.

As with cognitive flexibility, diverse thinking is thought to be a major component of creativity. Divergent thinking, as defined by Guilford (a pioneer in the field of creativity research; 1957), involves “going off in different directions” (p. 112); this can be contrasted with convergent thinking, which involves thinking that “converge[s] toward one right answer” (p. 112). Each of these types of thinking may be tapped, to varying degrees, by different tasks. Consider, for instance, a task in which one must list as many types of fruit as can be thought of in one minute. This would primarily require divergent thinking. Solving a riddle, on the other hand, would involve convergent thinking processes. Guilford originally identified divergent thinking as the primary type of thinking involved in creativity, although she also acknowledged a role for convergent

thinking in creative problem solving. Contemporary work recognizes that both types of thinking can contribute to overall creativity (Cropley, 2006).

In defining creativity, Guilford (1957) proposed that it is comprised of four, main components: elaboration, fluency, originality, and flexibility. With respect to flexibility, she identified two types. One type, she named spontaneous flexibility “because the examinee shows flexibility on his own initiative; the test items do not necessarily require it” (p. 114), and the other she titled adaptive flexibility “because it is important in the solution of problems – particularly those that require the discarding of familiar or habitual methods and striking out in new and unusual directions” (p. 114). She suggested that spontaneous flexibility is a type of personality trait, whereas adaptive flexibility refers to an ability to think flexibly; this definition of adaptive flexibility is similar to the concept of cognitive flexibility (Spiro et al., 1988).

Additional parallels between creativity and cognitive flexibility may be drawn from the existing literature. For instance, Ghacibeh, Shenker, Shenal, Uthman, & Heilman (2006) had participants complete a series of tasks including the Abbreviated Torrance Test for Adults (ATTA; Goff & Torrance, 2002) and an anagram solving task (Martindale & Greenough, 1973); The ATTA is a traditional measure of creativity and anagrams have been used as a measure of cognitive flexibility (Beverdort, Hughes, Steinberg, Lewis, & Heilman, 1999). Ghacibeh, et al. (2006) found that performance on both the ATTA and anagram solving task was significantly more impaired under conditions of vagus nerve stimulation than during sham stimulation. This suggests that creativity and cognitive flexibility are similarly affected by neurological stress.

Another factor which appears to affect both creativity and cognitive flexibility is mood. In a series of studies, Isen, Daubman and Nowicki (1987) investigated the facilitatory effects of positive mood on creativity. In one experiment, a positive, neutral, or negative mood, respectively, was induced by showing participants 5 min clips of either a comedy video, mathematics video, or documentary video depicting Nazi concentration camps. Following mood induction, participants were asked to complete Duncker’s (1945) candle task. In this task, individuals are shown an image of a box of tacks, a candle, and a

matchbook lying on a table. They are then asked how the candle may be fixed to a wall in such a way that, when lit, the wax does not drip onto the table below. To solve the task, participants must transcend functional fixedness and recognize that the box which the tacks are in could be emptied and tacked onto the wall as a stand for the candle.

Identifying this solution requires a degree of unconventional thinking and, so, this task has commonly been used as a measure of creativity. Isen et al. (1987) found that this task was solved by significantly more participants in the positive mood condition than in either of the other conditions.

Similar results were achieved in a subsequent experiment which assessed performance on the RAT (Mednick, 1962) after participants were either given a bag of candy, which induced a positive mood, or nothing, which induced a neutral mood. The RAT is a multi-item task which requires an individual to make unusual connections between words, and has traditionally been used to assess creative thinking. Overall performance on the RAT was unaffected by condition, possibly due to a restricted range of performance variability on the easiest and hardest items. Isen et al. divided the RAT into groups of easy, medium, and hard difficulty items. Separate analyses of each of these groups revealed that participants in the positive mood condition got significantly more medium difficulty items correct than participants in the neutral mood condition. Considered together, this work by Isen et al. (1987) suggests that creativity may be enhanced by positive mood.

Nadler, Rabi, and Minda (2010) have shown that cognitive flexibility is similarly enhanced by positive mood. In their study, music and video clips were implemented to induce a positive, neutral, or negative mood in participants. Participants then completed either a rule-defined or non-rule-defined category learning task. Cognitive flexibility facilitates the identification and testing of strategies and rules; consequently, cognitive flexibility is believed to play a larger role in the learning of rule-defined categories than in the learning of non-rule-defined categories (Ashby, Paul, & Maddox, 2011). Nadler et al. (2010) found an effect of mood on performance of the rule-defined category learning task, such that participants in the positive mood condition performed significantly better than participants in the neutral and negative mood conditions. Performance on the non-rule-defined category learning task, in contrast, was unaffected by mood condition. The

differential impact that mood was found to have on category learning suggests that it is cognitive flexibility that was affected by the mood manipulation, as opposed to a general process associated with category learning. Similar to creativity, therefore, cognitive flexibility appears to be facilitated by positive mood. (Refer to Figure 1.2 for a summary of the parallels between creativity and cognitive flexibility which have been discussed.)

Vagus nerve stimulation → Impaired creativity (Ghacibeh et al., 2006)
Vagus nerve stimulation → Impaired cognitive flexibility (Ghacibeh et al., 2006)
Positive mood → Enhanced creativity (Isen et al., 1987)
Positive mood → Enhanced cognitive flexibility (Nadler et al., 2010)
Moderate ambient noise → Enhanced creativity (Mehta et al., 2012)
Question of the current study: Moderate ambient noise → Enhanced cognitive flexibility?

Figure 1.2. Parallels in the creativity and cognitive flexibility literature.

1.6 The Present Studies

Mehta et al. (2012) concluded that creativity can be enhanced by moderate volumes of ambient noise. A relationship appears to exist between cognitive flexibility and creativity. As a result, it seems plausible that cognitive flexibility, like creativity, is enhanced by moderate volumes of ambient noise.

Study 1 (Chapter 2) was completed in a preliminary attempt to replicate the results of Mehta et al (2012). In this study, performance on three creativity tasks was compared across three conditions: control (i.e. no added noise), medium volume noise, and high volume noise. Study 2 (Chapter 3) employed the same three noise conditions as in Study 1, and extended this line of research from a focus of creativity to cognitive flexibility. Specifically, performance on a category learning task, which was designed to evaluate cognitive flexibility, was compared between the volume conditions.

The rationale and specific hypotheses for each study are presented in detail in the corresponding chapters of this thesis. Broadly, however, it was predicted that performance would be maximized under conditions of moderate ambient noise. A confirmation of this hypothesis in Study 1 would provide support for Mehta et al. (2012) by demonstrating that moderate volumes of ambient noise enhance creativity. Further support for this prediction in Study 2 would suggest that moderate volumes of ambient noise may also enhance cognitive flexibility. An overall analysis of the two studies, and the implications of each, is presented in a general discussion section (Chapter 4).

Chapter 2

2 Study 1

The aim of this thesis was to extend the work of Mehta et al. (2012) and assess how cognitive flexibility is affected by ambient noise. Study 2 was conducted for this purpose. However, because Study 2 was modeled largely after Mehta et al., Study 1 was first conducted to establish the replicability of their findings. Study 1, therefore, examined the effects of ambient noise on creativity.

2.1 Convergent and Divergent Thinking

Creativity is influenced by two types of thinking: convergent and divergent thinking (Cropley, 2006). Defined concisely, “[d]ivergent thinking involves production of variability, convergent thinking production of singularity,” (Cropley, 1999, p. 254). These thinking processes are essentially opposites of one another and, thus, are often differentially involved in various tasks. The RAT (Mednick, 1962), for instance, is a multi-item test for which there is only one correct response for each item. Completing the RAT, therefore, demands a high degree of convergent thinking. The RAT has traditionally been viewed as a measure of creativity because it requires that individuals make unusual associations between words; it was also one of the tasks used by Mehta et al. (2012). In addition to the RAT, Mehta et al. examined the effects of volume on performance of the Brick Uses task (Wilson et al., 1954), an idea generation task, and a problem solving task (Burroughs and Mick, 2004). For each of these tasks, participants were required to list as many solutions as possible (i.e. as many uses for a brick that they could think of, as many ideas for a new product that they could think of, and as many potential solutions to a problem that they could think of); these tasks, therefore, tap primarily into divergent thinking.

In every task that they considered, both convergent and divergent thinking based, Mehta et al. (2012) found that performance was enhanced by moderate volumes of ambient noise. To substantiate these findings, Study 1 implemented three tasks which differentially require each type of thinking: the Compound Remote Associates (CRA;

Bowden & Jung-Beeman, 2003) task, an insight problem task, and the Alternate Uses task (AUT; Guilford, Christensen, Merrifield, & Wilson, 1960).

2.1.1 Convergent Thinking Tasks

Developed by Bowden and Jung-Beeman (2003), the CRA is an updated version of Mednick's (1962) RAT. The original RAT is fairly short, consisting of two alternative versions comprised of 30 items each. The CRA was designed to be a longer, valid and reliable substitute for the RAT. Given that it is a newer task with updated items, the CRA may also be more comprehensive than the RAT. The CRA does, however, maintain a similar structure to the RAT: it is comprised of a number of items, each consisting of three words. The solution for each item is a single word which, when combined with each of the three words in the item, forms a new word or phrase. For instance, the solution for the item "flower / friend / scout" is "girl" because the word "girl" can be combined with each word in the item to form the phrases "flower girl," "girlfriend," and "girl scout." For each item, only one word is considered to be a correct solution. The CRA, therefore, relies primarily on convergent thinking and was selected as a measure of convergent-based creativity for Study 1.

Insight problems, or riddles, are similar to the CRA in that each problem has only one correct answer. Solving insight problems thus, necessitates a high degree of convergent thinking; it also requires a certain degree of creativity because flexible thought and a shifting of perspectives is often crucial for identifying the answer (Dow & Mayer, 2004). According to Dow and Mayer (2004), insight problems may be divided into three primary types: verbal, for which "[t]he distinguishing feature ... is that it contains a word or phrase that must be interpreted in an unobvious way" (p. 391); mathematical, for which "[t]he distinguishing feature ... is that it looks like an arithmetic word problem but it is not solved by simple computation" (p. 391); and spatial, for which "[t]he distinguishing feature ... is that they imply a constraint that is really not part of the problem" (p. 391). When asked to categorize insight problems, these three types were readily and consistently identified by participants. Furthermore, domain specific training on how to solve the problems translated into domain specific improvements in performance (Dow & Mayer, 2004). This suggests that these types of problems are objectively different from

one another. Consequently, an insight problem task, including each of the three types of problems, was designed as a second measure of convergent creativity for Study 1.

2.1.2 Divergent Thinking Task

The third creativity task used in Study 1 was the AUT (Guilford et al., 1960). The AUT is a revised version of the Unusual Uses task, which was created as part of a battery of tests intended to measure facets of creativity (Wilson et al., 1954). Both the Unusual Uses task and AUT have since been used extensively in research as measures of creative thinking (a review of some of this work is presented in Guilford et al., 1960). The Brick Uses task implemented by Mehta et al. (2012) is a simplified version of the Unusual Uses task. In both the Unusual Uses task and AUT, participants are presented with the names of common objects. For each object, participants are asked to list purposes for which the object could be used, other than those for which the object is intended. Any response which names a use that is realistically possible, and is different from the common use, is considered acceptable. Participants are not limited to producing a single, correct answer; instead multiple responses may be correct. Consequently, the AUT relies primarily on divergent thinking and was chosen as a measure of divergent-based creativity in this study.

2.2 Processing Difficulty and Cognitive Abstraction

In addition to measuring creative performance, Study 1 considered the effects of ambient noise on processing difficulty and cognitive abstraction. Mehta et al. (2012) suggested that ambient noise enhanced creativity indirectly, by increasing processing difficulty and cognitive abstraction. Respectively, these variables were measured via a processing difficulty index, which was computed by averaging scores on Likert scales regarding perceived distraction, and the BIF, which provides a measure of construal level (i.e. degree of cognitive abstraction; Vallacher, & Wegner, 1989). Mehta et al. (2012) found that moderate volumes of noise were associated with increased scores on both the index and BIF, as well as enhanced performance on creativity tasks. A multiple mediation analysis suggested a path from ambient noise to processing difficulty, followed by

cognitive abstraction and, ultimately, creativity. Study 1, therefore, also assessed the effects of noise on these intermediate variables.

2.3 Individual Differences

Mehta et al. (2012) suggested that this relationship between noise, processing difficulty, abstraction, and creativity is moderated by baseline creativity. Individual differences may also moderate the effect that noise has on attention (Söderlund et al., 2010).

Consequently, Study 1 considered the potentially moderating effects of individual differences: in particular, differences in preferred work environments. This factor is especially relevant to Study 1, given that all participants were university students. Some students prefer to complete their work in environments such as coffee shops or while listening to music, and others prefer to work in silence. Individuals who actively seek noisy environments may be particularly prone to some of the facilitatory effects of noise on performance. On the other hand, their propensity to work with noise may mean that they are better at stimulus filtering and, as a result, are unaffected by the presence of ambient noise. Study 1, therefore, explored the possibility that the effect of noise on creativity is moderated by individual differences in preference for noisy work environments.

2.4 Purpose and Hypotheses

The primary purpose of Study 1 was to determine if creativity is affected by ambient noise. This study also sought to assess whether the relationship between these factors is influenced by processing difficulty, cognitive abstraction, and individual differences in preferred work environments. Study 1, therefore, replicated and expanded the work of Mehta et al. (2012).

Study 1 employed three conditions: control, medium volume noise, and high volume noise. Based on the results of Mehta et al. (2012), the following predictions were made: (1) performance on all creative thinking tasks would be optimal for participants in the medium volume condition, (2) performance would be equivalent for participants in the control and high volume conditions, (3) both the control and high volume conditions

would be associated with creative performance that was significantly lower than that of participants in the medium volume condition, and (4) a positive relationship would be found between volume and both processing difficulty and abstraction. Furthermore, results supporting these hypotheses were expected to be qualified by individual differences in preferred work environments. One of two possibilities was anticipated: compared to those who like to work in silence, an effect of noise on creativity would be either more or less apparent for those who like to work in noisy environments.

2.5 Method

2.5.1 Participants

Ninety undergraduate students from the University of Western Ontario participated in this study. All participants had normal, or corrected to normal, hearing and visual acuity, and spoke English as a first language. Participants were recruited through the Western Psychology Research Participation Pool, and received course credit for their participation.

2.5.2 Materials

2.5.2.1 Compound Remote Associate Task

Data from a large ($n = 289$) CRA norming study was obtained from Jung-Beeman. All 144 CRA items were ordered from easiest to most difficult, based on the number of individuals in the norming study who were able to solve each item in 30 s. The list of problems was then divided into thirds, and 10 problems were randomly selected from each third of the list. The resulting selection of 30 items, therefore, consisted of 10 items of easy difficulty, 10 items of medium difficulty, and 10 items of hard difficulty. (Refer to Appendix A for a list of the 30 selected CRA items.)

2.5.2.2 Insight Problem Task

A series of verbal, mathematical, and spatial insight problems was obtained from Dow (and is freely available at <http://www.indiana.edu/~bobweb/Handout/d4.ips.htm>). Two problems of each type were randomly selected. The insight problem task, therefore, consisted of two verbal insight problems, two mathematical insight problems, and two

spatial insight problems. (The six selected insight problems are presented in Appendix B.)

2.5.2.3 Alternate Uses Task

The AUT was purchased for use in this study from Mind Garden, Inc. (www.mindgarden.com). Form B was arbitrarily chosen for use in this study. (Refer to Appendix C for a sample of items from this version of the AUT.) Traditionally, the AUT is a paper and pencil task divided into two parts of three items each. For this study, the task was adapted to be completed using a computer. Several methodological changes were made: each of the six items of Form B was shown individually, participants were required to complete one item at a time, participants were not permitted to return to an incomplete item later in the task, and the 8 min typically allotted for the entire task (4 min for each of the two parts) was divided by six. The six AUT items, therefore, were presented individually for 80 s each.

2.5.2.4 Auditory Stimulus

The auditory stimulus for this study was streamed from the website coffitivity.com. This website provides various tracks consisting of pre-recorded sounds from environments, such as coffee shops and university cafeterias, played on a continuous loop. The track “Morning Murmur” was arbitrarily chosen to be used in this study. The audio from coffitivity.com was presented through speakers placed on a desk located approximately 1.8 m behind participants. The volume of these speakers was measured using a Brüel & Kjær Integrating Sound Level Meter placed on the desks where participants were seated during the study. The speakers were adjusted to create the medium and high volume conditions. The speakers were shut off for the control condition, although the ambient volume of the room was still measured and recorded. Because the ambient volume of the room varied throughout the testing period (due to factors such as building construction and rain, for example), the volume was measured and the speakers were adjusted as needed for each testing session. The volume of “Morning Murmur” varies throughout the duration of the track and some changes in the ambient noise surrounding the testing room were unavoidable; as a result, precise volumes could not be obtained for the three volume

conditions. As in Mehta et al. (2012), the target volumes for the medium and high volume conditions were 70 and 85 dB, respectively. The actual volumes for the three conditions, averaged across all readings, were approximately 31 dB, 67 dB, and 81 dB for the control, medium, and high volume conditions, respectively.

2.5.2.5 Follow-up Questionnaires

Follow-up questionnaires were completed by all participants. The questionnaires consisted of four parts: the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988), the BIF (Vallacher & Wegner, 1989) four Likert scales, and two open-ended questions. (Refer to Appendix D for a copy of the follow-up questionnaire.)

2.5.2.5.1 Positive and Negative Affect Schedule

Although Mehta et al. (2012) did not find an effect of noise-induced mood on creativity, Isen et al. (1987) found that positive mood enhances performance on both Duncker's candle task and the RAT. Therefore, to account for the possibility that mood is a mediating variable between ambient noise and creativity (i.e. that ambient noise enhances mood which, in turn, enhances creativity), participants were asked to complete the PANAS (Watson et al., 1988).

The PANAS measures an individual's current mood, and consists of ten positive and ten negative mood descriptor words. Each descriptor is to be rated based on the extent to which an individual identifies with it "right now, that is at the present moment" (Watson et al., 1988, p. 1070). Ratings are made on a scale of 1, meaning "not at all", to 5, meaning "extremely." Following completion, ratings are averaged for the positive and negative words, resulting in positive and negative affect scales for each individual.

2.5.2.5.2 Behavior Identification Form

The BIF is a 25 item form which provides a measure of construal level. Each item states a behaviour and two alternate ways to describe the behaviour. One option describes the mechanics of how the behaviour is performed (low level construal) and the other focuses more on the purposes behind the behaviour (high level construal). For each item,

participants are asked to select the option which they feel best describes the behaviour. For each participant, the number of high level options selected is summed to provide a measure of construal level.

2.5.2.5.3 Likert Scales

To ensure that the conditions were perceptually different, participants were asked to indicate, on a scale of 1 (“Not at all distracting”) to 7 (“Very distracting”), how distracting they found the background noise while they were completing the task. A seven-point Likert scale was also used to assess how easily participants were able to complete each of the three creative thinking tasks. In particular, participants were asked to indicate, on a scale of 1 (“Not at all difficult”) to 7 (“Very difficult”), how difficult they found each task. For each participant, scores from these items were averaged to create a processing difficulty index.

2.5.2.5.4 Open-Ended Questions

To assess individual differences in preference for noise, participants were asked to complete two open-ended questions. The first question asked participants to indicate if they liked to study or work with music playing in the background. The second question asked participants to describe the types of environments in which they usually like to study or work. Answers to this second question were not analyzed and are not considered further.

2.5.3 Procedure

Participants were tested in pairs. Each pair was randomly assigned to one of the three volume conditions: control ($n = 30$), medium volume noise ($n = 30$), or high volume noise ($n = 30$). The conditions were prepared before participants arrived in the lab. After providing informed consent, participants were given a verbal explanation of how to complete each of the three creativity tasks. Participants were provided with paper and pencils to assist them in solving the insight problem task. They were then seated at computers and, if they had been assigned to the medium or high volume conditions, the

speakers were turned on. If participants were in the control condition, the speakers were left off.

PsychoPy (Peirce, 2007) software was used to present the CRA task, insight problem task, and AUT to participants on Macintosh computers. Order effects were not expected with respect to the tasks and all participants completed the tasks in the same order. Participants were first shown a series of instructions which explained how to complete the CRA task. Three practice items were then presented, one at a time. These practice items were different than the 30 items which comprised the main portion of the task. All three practice items were of easy difficulty. After participants typed their answers on the computer keyboard, they were provided written feedback in the form of “correct” or “incorrect,” followed by the correct answer. Participants then began the primary task. All 30 CRA items were presented one at a time and the order of items was randomized for each participant. Participants typed their responses on the computer keyboard and were not provided feedback for these items. Each item was shown on the screen for 30 s. Following this initial 30 s, participants were provided an additional 10 s to finish typing. A new item was automatically presented after this 40 s had elapsed.

Once the CRA task was complete, a message on the screen indicated that the first task was over. The six insight problems were then presented one at a time for 90 s each. The order of items was randomized for each participant, and participants typed their responses on the keyboard. Once the insight problem task was complete, a message on the screen indicated that the second task was over. Participants were then shown a series of instructions regarding how to complete the AUT. These instructions included the presentation of a sample item and six, acceptable responses for that item. The six AUT items were then presented one at a time for 80 s each. The order of items was maintained constant across participants and reflected the order in which they appear in Guilford et al. (1960). Participants typed their responses on the keyboard. When the AUT was complete, the noise (if present) was turned off. Participants then completed the follow-up questionnaire via paper and pencil. (Refer to Figure 2.1 for a visual depiction of the task procedure.)

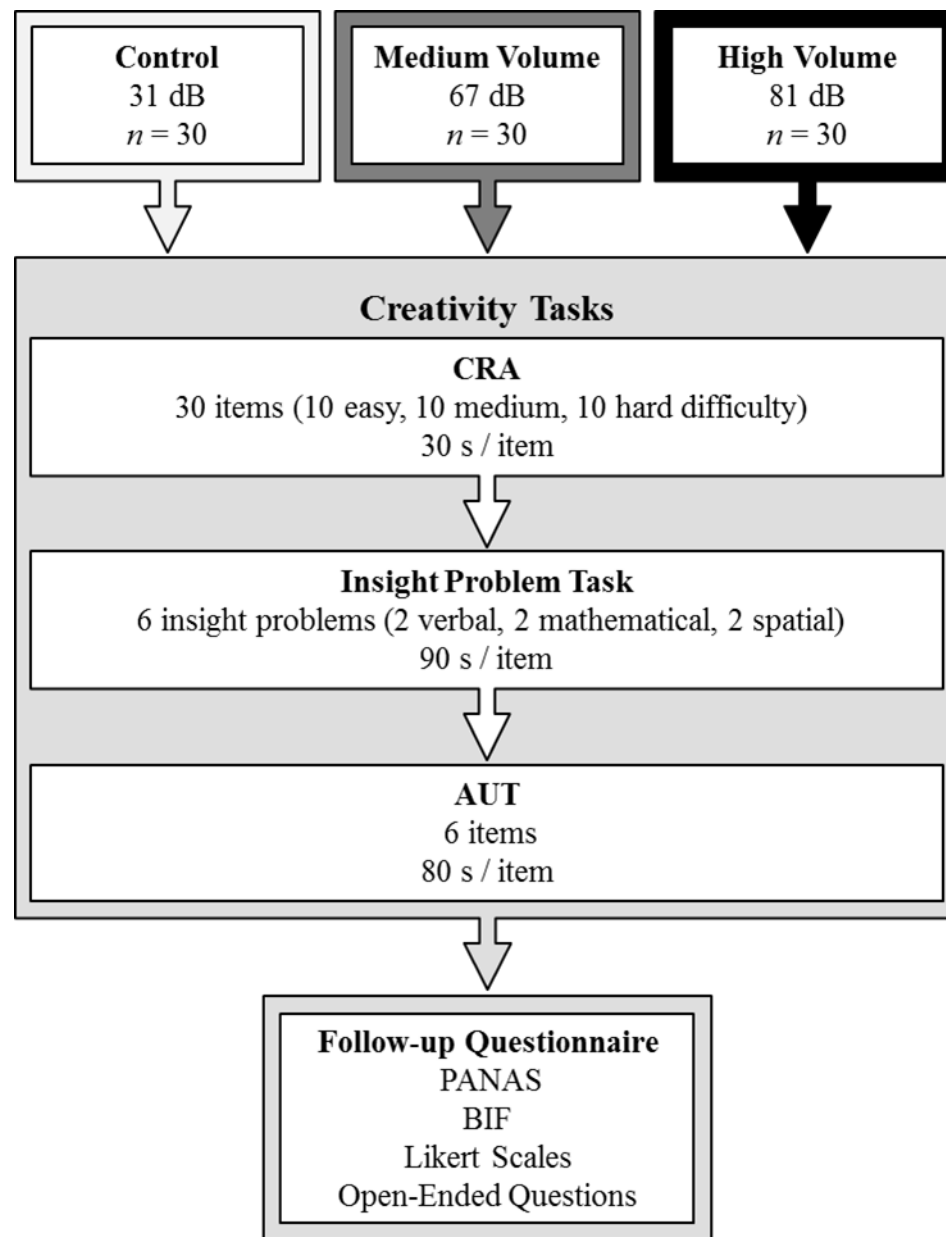


Figure 2.1. Experimental procedure for Study 1. Participants were assigned to one of three volume conditions and completed three creativity tasks. This was followed by the completion of a four-part questionnaire.

2.5.4 Data Cleaning

The PsychoPy (Peirce, 2007) program automatically scored answers to the CRA and insight problem task as either incorrect or correct. All responses were manually assessed, however, and any answers which had been scored as incorrect due to common spelling errors (e.g. “soar” instead of “sore”) were changed to “correct.” Additionally, any correct

answers in the CRA task, for which the first key-press occurred after the initial 30 s response period, were marked as incorrect.

2.5.5 Scoring the Alternate Uses Task

Responses made for each item by each participant were scored on five dimensions according to Guilford et al. (1960) and Hommel, Colzato, Fischer, and Christoffels (2011).

1. Fluency: The total number of responses given.
2. Acceptability: The total number of acceptable responses. For a response to be acceptable, it must have been both realistically possible and different from the stated common use. Acceptable responses were given a score of 1 and unacceptable responses a score of 0. Only acceptable responses were included in the subsequent scores for originality, flexibility, and elaboration.
3. Originality: A score of how original each individual response was compared to all responses from all participants. Each response was given a score of 1 or 2 if the same response was given by only 5% or 1% of the other participants, respectively. (Note that, because 1% of 90 is 0.9, and it would be impossible for a response to be given by 0.9 other participants, percentages were rounded to the nearest whole number. A response calculated to be given by 1.11% of other participants, for example, was, therefore, rounded to 1% and given a score of 2.) All other responses were given a score of 0. These scores were summed for each participant. The more responses given by a participant, the higher their score of originality is likely to be. To account for this contamination problem, the final originality score for each participant was calculated as the sum of originality scores divided by the number of acceptable responses.
4. Flexibility: The number of different categories of responses.
5. Elaboration: A score of how detailed each response was. Each response was scored on a scale of 0 (no detail) to 2 (very detailed regarding how or why the

item may be used for the stated purpose). These scores were summed for each participant.

All responses were scored by an independent rater.

2.6 Results

2.6.1 All Participants

Analyses were first conducted to assess the effect of volume on creative performance for all participants. Refer to Table 2.1 for the descriptive statistics associated with the following variables: CRA task performance (overall and divided by item difficulty), insight problem task performance (overall and divided by item type), AUT performance, PANAS scales (for positive and negative affect), BIF score, Likert scales (for perceived task difficulty and level of distraction), and processing difficulty index score.

2.6.1.1 CRA Task

A 3x3 mixed analysis of variance (ANOVA) was conducted with volume condition as a between-subjects factor and item difficulty as a within-subjects factor. A significant main effect of condition on overall CRA performance was not observed; $F(2, 87) = 0.20, p = .82$. A significant main effect of item difficulty was found; $F(2, 174) = 199.90, p < .001, \eta^2 = .70$. Bonferroni corrected post-hoc tests revealed that participants got significantly more easy difficulty items correct than both medium and hard difficulty items.

Participants also got significantly more medium difficulty items correct than hard difficulty items (for all comparisons, $p < .001$). A significant interaction between condition and difficulty was revealed; $F(4, 174) = 2.53, p = .04, \eta^2 = .06$.

Independent samples t-tests revealed no significant effect of condition on performance for the easy and hard difficulty items (for all analyses, $p > .05$). With respect to the 10 medium difficulty items, an independent samples t-test found that participants in the medium volume condition got significantly more items correct than participants in the high volume condition; $t(58) = 2.31, p = .02, d = .60$. A significant performance difference was not observed between the control and medium volume conditions or the

Table 2.1. Means and standard deviations for each volume condition when variables were analyzed for all participants.

Variable	Condition					
	Control		Medium Volume		High Volume	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Number of Correct CRA Items						
Overall	8.07	3.25	8.40	3.23	7.87	3.37
Easy Items	4.67	1.75	4.70	1.78	4.70	1.84
Medium Items*	2.23	1.65	2.90	1.71	1.97	1.40
Hard Items	1.17	.91	.80	.71	1.20	1.16
Number of Correct Insight Problems						
Overall	2.23	1.31	2.70	1.18	2.50	1.23
Mathematical	1.37	.67	1.50	.57	1.37	.62
Verbal	.70	.79	.77	.73	.77	.73
Spatial	.17	.38	.43	.57	.37	.49
AUT Performance						
Fluency	21.07	6.99	21.63	7.12	20.67	6.17
Acceptability	13.07	6.10	14.87	5.53	14.30	4.58
Originality	.45	.32	.50	.27	.45	.25
Flexibility	11.53	5.44	12.90	4.81	12.17	3.85
Elaboration	9.97	5.93	12.30	6.80	10.17	5.00
PANAS						
Positive Affect	2.51	.59	2.63	.63	2.45	.65
Negative Affect*	1.43	.45	1.62	.44	1.97	.75
BIF						
Construal Level	15.73	4.35	15.67	5.29	14.50	5.10
Likert Scales						
CRA Difficulty	4.83	1.15	5.20	1.10	5.48	1.16
Insight Difficulty*	4.07	1.26	4.13	1.17	4.80	1.38
AUT Difficulty	4.10	1.47	4.20	1.32	4.63	1.52
Distraction*	1.96 ^a	1.26	4.30	1.44	4.83	1.56
Processing Difficulty Index						
Score*	3.69 ^a	.70	4.46	.67	4.94	.89

Notes: CRA = Compound Remote Associates, AUT = Alternate Uses task, PANAS = Positive and Negative Affect Schedule, BIF = Behavior Identification Form. ^a $n = 28$. * $p \leq .05$ (denotes a significant effect of volume condition on performance/score).

control and high volume conditions; $t(58) = 1.54$, $p = .13$ and $t(58) = 0.67$, $p = .50$, respectively.

2.6.1.2 Insight Problem Task

A 3x3 mixed ANOVA was conducted with volume condition as a between-subjects factor and problem type as a within-subjects factor. Levene's test revealed that there was

a violation of homogeneity of between-group variance for spatial insight problem performance; $F(2, 87) = 11.67, p < .001$. Because sample sizes were equal, however, it is unlikely that results were affected by this violation (Gardner & Tremblay, 2007). A significant main effect of condition on overall insight problem performance was not observed; $F(2, 87) = 1.07, p = .35$. A significant main effect of problem type was found; $F(2, 174) = 80.58, p < .001, \eta^2 = .48$. Bonferroni corrected post-hoc tests revealed that participants got significantly more mathematical problems correct than both verbal and spatial problems. Participants also got significantly more verbal problems correct than spatial problems (for all comparisons, $p < .001$). A significant interaction between condition and problem type was not revealed; $F(4, 174) = 0.37, p = .83$.

2.6.1.3 AUT

ANOVAs revealed no significant effect of condition on the degree of fluency, acceptability, originality, flexibility, or elaboration of responses provided by participants for the AUT; $F(2, 87) = 0.15, p = .86$; $F(2, 87) = 0.86, p = .43$; $F(2, 87) = 0.25, p = .78$; $F(2, 87) = 0.62, p = .54$; and $F(2, 87) = 1.41, p = .25$, respectively.

2.6.1.4 PANAS

An ANOVA revealed no significant effect of condition on positive affect; $F(2, 87) = 0.62, p = .54$. With respect to negative affect, Levene's test indicated that the assumption of homogeneity of variances was violated; $F(2, 87) = 6.62, p = .002$. Welch's F-test revealed a significant effect of condition on negative affect; $F(2, 55.89) = 5.81, p = .01, \eta^2 = .17$. A Games-Howell post-hoc test indicated that participants in the high volume condition scored significantly higher on the negative affect scale than participants in the control condition ($p = .004$). A significant difference in negative affect was not observed between the control and medium volume conditions ($p = .24$) or the medium and high volume conditions ($p = .08$).

2.6.1.5 BIF

An ANOVA revealed no significant effect of condition on BIF score; $F(2, 87) = 0.59, p = .55$.

2.6.1.6 Likert Scales

2.6.1.6.1 Difficulty

An ANOVA revealed no significant effect of condition on perceived task difficulty for the CRA task or the AUT; $F(2, 87) = 2.47, p = .09$ and $F(2, 87) = 1.16, p = .32$, respectively. With respect to the insight problem task, an ANOVA revealed a marginally significant effect of condition on perceived difficulty; $F(2, 87) = 3.06, p = .05, \eta^2 = .07$. LSD post-hoc tests revealed that participants in the high volume condition rated the insight problem task as significantly more difficult than participants in the control condition ($p = .03$) and marginally more difficult than participants in the medium volume condition ($p = .05$). A significant difference in perceived difficulty was not observed between the control and medium volume conditions ($p = .84$).

2.6.1.6.2 Distraction

Two participants (both in the control condition) did not provide a response as to how distracting they found the background noise. With respect to the rest of the participants, an ANOVA revealed a significant effect of condition on perceived level of distraction; $F(2, 85) = 32.73, p < .001, \eta^2 = .44$. Tukey post-hoc tests revealed that participants in the control condition rated the ambient noise as significantly less distracting than participants in both the medium and high volume conditions (for both comparisons, $p < .001$). A significant difference in perceived distraction was not observed between the medium and high volume conditions ($p = .32$).

2.6.1.7 Processing Difficulty Index

The processing difficulty index was computed by averaging scores on the Likert scales; therefore, index scores were not computed for the two participants who did not provide a response regarding their perceived level of distraction. With respect to the rest of the participants, an ANOVA revealed a significant effect of condition on perceived processing difficulty; $F(2, 85) = 19.62, p < .001, \eta^2 = .32$. Tukey post-hoc tests revealed that participants in the high volume condition scored significantly higher on the processing difficulty index than participants in the control condition ($p < .001$) and marginally higher than participants in the medium volume condition ($p = .05$).

Participants in the medium volume condition scored significantly higher on the index than participants in the control condition ($p = .001$).

2.6.1.8 Preference for Studying or Working with Music

Responses to the first open-ended question generally fell into one of three categories: yes, no, or sometimes. (Many participants indicated that they liked to listen to music for some types of work, like math or problem solving, but not for other types of work, such as reading.) Twenty-six participants stated that they do not like to listen to music while studying or working, 33 indicated that they occasionally like to listen to music while studying or working, and 30 stated they do like to listen to music while studying or working. One participant (in the control condition) did not provide a response to this question. Table 2.2 depicts the spread of participants, who did respond, across the three volume conditions based on their study/work preferences. The data was divided based on study/work preferences and analyses were repeated for each subgroup.

Table 2.2. Participants divided by volume condition and their stated preference for listening to music while they study/work.

Like to Study/Work with Music	Volume Condition		
	Control	Medium	High
No	$n = 6$	$n = 8$	$n = 12$
Sometimes	$n = 9$	$n = 16$	$n = 8$
Yes	$n = 14$	$n = 6$	$n = 10$

2.6.2 Participants Who Do Not Listen to Music While Studying/Working

Analyses were conducted to assess the effect of volume on creative performance for participants who indicated that they do not like to listen to music while they study/work. Refer to Table 2.3 for the descriptive statistics associated with the following variables: CRA task performance (overall and divided by item difficulty), insight problem task performance (overall and divided by item type), AUT performance, PANAS scales (for positive and negative affect), BIF score, Likert scales (for perceived task difficulty and level of distraction), and processing difficulty index score.

Table 2.3. Means and standard deviations for each volume condition when variables were analyzed for participants who do not like to listen to music while they work/study.

Variable	Condition					
	Control		Medium Volume		High Volume	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Number of Correct CRA Items						
Overall	8.83	3.43	7.75	2.77	7.33	3.37
Easy Items	5.33	1.21	4.00	1.31	4.25	1.82
Medium Items	1.83	1.33	3.00	1.69	2.00	1.60
Hard Items	1.67	1.21	.75	.71	1.08	1.17
Number of Correct Insight Problems						
Overall	2.67	1.63	2.38	1.30	2.08	1.17
Mathematical	1.67	.52	1.25	.71	1.33	.49
Verbal	.83	.98	.63	.92	.58	.79
Spatial	.17	.41	.50	.54	.17	.39
AUT Performance						
Fluency	24.17	5.42	21.50	5.40	20.33	5.88
Acceptability	18.17	5.71	15.63	3.82	13.75	5.63
Originality	.56	.22	.38	.22	.42	.28
Flexibility	16.33	4.93	13.50	3.55	11.67	5.02
Elaboration	12.33	8.21	10.88	4.19	10.42	6.53
PANAS						
Positive Affect	2.25	.65	2.66	.52	2.23	.58
Negative Affect*	1.27	.23	1.89	.41	2.17	.99
BIF						
Construal Level	16.33	3.50	13.63	5.95	15.17	6.38
Likert Scales						
CRA Difficulty	4.50	1.23	5.25	1.17	5.00	1.04
Insight Difficulty	3.67	.82	4.38	1.19	5.17	1.47
AUT Difficulty	4.50	1.87	4.13	1.55	4.33	1.56
Distraction*	1.80 ^a	1.30	4.75	1.49	4.92	2.02
Processing Difficulty Index						
Score*	3.40 ^a	.78	4.63	.83	4.85	1.03

Notes: CRA = Compound Remote Associates, AUT = Alternate Uses task, PANAS = Positive and Negative Affect Schedule, BIF = Behavior Identification Form. ^a $n = 5$. * $p \leq .05$ (denotes a significant effect of volume condition on performance/score).

2.6.2.1 CRA Task

A 3x3 mixed ANOVA was conducted with volume condition as a between-subjects factor and item difficulty as a within-subjects factor. A significant main effect of condition on overall CRA performance was not observed; $F(2, 23) = 0.44, p = .65$. A significant main effect of item difficulty was found; $F(2, 46) = 54.72, p < .001, \eta^2 = .70$. Bonferroni corrected post-hoc tests revealed that participants got significantly more easy

difficulty items correct than both medium and hard difficulty items (for both comparisons, $p < .001$). Participants also got significantly more medium difficulty items correct than hard difficulty items ($p = .004$). A marginally significant interaction between condition and difficulty was revealed; $F(4, 46) = 2.51, p = .05, \eta^2 = .18$. Independent samples t-tests, however, revealed no significant effect of condition on performance for the easy, medium, or hard difficulty items (for all analyses, $p > .05$).

2.6.2.2 Insight Problem Task

A 3x3 mixed ANOVA was conducted with volume condition as a between-subjects factor and problem type as a within-subjects factor. A significant main effect of condition on overall insight problem performance was not observed; $F(2, 23) = 0.41, p = .67$. A significant main effect of problem type was found; $F(2, 46) = 22.66, p < .001, \eta^2 = .50$. Bonferroni corrected post-hoc tests revealed that participants got significantly more mathematical problems correct than both verbal ($p = .001$) and spatial ($p < .001$) problems. A significant difference in performance was not observed with respect to the verbal and spatial problems ($p = .15$). A significant interaction between condition and problem type was not revealed; $F(4, 46) = 0.75, p = .56$.

2.6.2.3 AUT

ANOVAs revealed no significant effect of condition on the degree of fluency, acceptability, originality, flexibility, or elaboration of responses provided by participants for the AUT; $F(2, 23) = 0.93, p = .41$; $F(2, 23) = 1.48, p = .25$; $F(2, 23) = 1.01, p = .38$; $F(2, 23) = 2.07, p = .15$; and $F(2, 23) = 0.18, p = .83$, respectively.

2.6.2.4 PANAS

An ANOVA revealed no significant effect of condition on positive affect; $F(2, 23) = 1.53, p = .24$. With respect to negative affect, Levene's test indicated that the assumption of homogeneity of variances was violated; $F(2, 23) = 16.68, p < .001$. Welch's F-test revealed a significant effect of condition on negative affect; $F(2, 15.08) = 8.97, p = .003, \eta^2 = .54$. A Games-Howell post-hoc test indicated that participants in the control condition scored significantly lower on the negative affect scale than participants in both

the medium ($p = .01$) and high ($p = .03$) volume conditions. A significant difference in negative affect was not observed between the medium and high volume conditions ($p = .66$).

2.6.2.5 BIF

An ANOVA revealed no significant effect of condition on BIF score; $F(2, 23) = 0.40$, $p = .68$.

2.6.2.6 Likert Scales

2.6.2.6.1 Difficulty

An ANOVA revealed no significant effect of condition on perceived task difficulty for the CRA task, insight problem task, or AUT; $F(2, 23) = 0.78$, $p = .47$; $F(2, 23) = 2.95$, $p = .07$; and $F(2, 23) = 0.09$, $p = .91$, respectively.

2.6.2.6.2 Distraction

In this group of participants, one (in the control condition) did not provide a response as to how distracting they found the background noise. With respect to the rest of the participants, an ANOVA revealed a significant effect of condition on perceived level of distraction; $F(2, 22) = 6.11$, $p = .01$, $\eta^2 = .36$. Tukey post-hoc tests revealed that participants in the control condition rated the ambient noise as significantly less distracting than participants in both the medium ($p = .02$) and high ($p = .01$) volume conditions. A significant difference in perceived distraction was not observed between the medium and high volume conditions ($p = .98$).

2.6.2.7 Processing Difficulty Index

An index score was not computed for the participant who did not provide a response regarding their perceived level of distraction. With respect to the rest of the participants, an ANOVA revealed a significant effect of condition on perceived processing difficulty; $F(2, 22) = 4.44$, $p = .02$, $\eta^2 = .32$. A Tukey post-hoc test revealed that participants in the high volume condition scored significantly higher on the processing difficulty index than participants in the control condition ($p = .02$). A significant difference in index score was

not observed between the medium volume and control conditions ($p = .08$) or the medium and high volume conditions ($p = .85$).

2.6.3 Participants Who Sometimes Listen to Music While Studying/Working

Analyses were conducted to assess the effect of volume on creative performance for participants who indicated that they sometimes like to listen to music while they study/work. Refer to Table 2.4 for the descriptive statistics associated with the following variables: CRA task performance (overall and divided by item difficulty), insight problem task performance (overall and divided by item type), AUT performance, PANAS scales (for positive and negative affect), BIF score, Likert scales (for perceived task difficulty and level of distraction), and processing difficulty index score.

2.6.3.1 CRA Task

A 3x3 mixed ANOVA was conducted with volume condition as a between-subjects factor and item difficulty as a within-subjects factor. A significant main effect of condition on overall CRA performance was not observed; $F(2, 30) = 0.82, p = .45$. A significant main effect of item difficulty was found; $F(2, 60) = 51.96, p < .001, \eta^2 = .63$. Bonferroni corrected post-hoc tests revealed that participants got significantly more easy difficulty items correct than both medium and hard difficulty items (for both comparisons, $p < .001$). Participants also got significantly more medium difficulty items correct than hard difficulty items ($p = .003$). A significant interaction between condition and difficulty was not revealed; $F(4, 60) = 1.64, p = .18$.

2.6.3.2 Insight Problem Task

A 3x3 mixed ANOVA was conducted with volume condition as a between-subjects factor and problem type as a within-subjects factor. A significant main effect of condition on overall insight problem performance was not observed; $F(2, 30) = 0.85, p = .44$. A significant main effect of problem type was found; $F(2, 60) = 23.74, p < .001, \eta^2 = .44$. Bonferroni corrected post-hoc tests revealed that participants got significantly more mathematical problems correct than both verbal ($p = .001$) and spatial ($p < .001$)

Table 2.4. Means and standard deviations for each volume condition when variables were analyzed for participants who sometimes like to listen to music while they work/study.

Variable	Condition					
	Control		Medium Volume		High Volume	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Number of Correct CRA Items						
Overall	8.00	3.81	8.50	3.43	6.50	3.78
Easy Items	4.22	2.05	4.69	1.85	4.00	1.60
Medium Items	2.44	1.94	2.81	1.76	1.25	1.28
Hard Items	1.33	.87	1.00	.73	1.25	1.39
Number of Correct Insight Problems						
Overall	2.22	1.30	2.94	1.29	2.63	1.41
Mathematical	1.22	.67	1.44	.51	1.50	.54
Verbal	.78	.83	.94	.68	.63	.74
Spatial	.22	.44	.56	.63	.50	.54
AUT Performance						
Fluency	19.56	8.38	22.88	7.33	21.50	7.75
Acceptability	10.56	5.88	15.56	5.92	14.63	5.32
Originality*	.27	.22	.58	.26	.57	.26
Flexibility	9.33	5.20	13.69	4.95	12.63	4.07
Elaboration	8.33	5.64	14.44	7.87	9.13	3.36
PANAS						
Positive Affect	2.76	.40	2.47	.58	2.63	.76
Negative Affect	1.52	.69	1.52	.40	1.92	.59
BIF						
Construal Level	15.11	3.82	16.69	4.44	14.88	3.48
Likert Scales						
CRA Difficulty	4.67	1.00	5.25	1.24	5.94	1.21
Insight Difficulty	4.33	1.58	4.19	1.05	4.50	1.51
AUT Difficulty	3.56	1.24	4.13	1.20	5.00	1.77
Distraction*	1.89	1.54	4.13	1.41	5.00	1.41
Processing Difficulty Index						
Score*	3.61	.71	4.42	.55	5.11	.99

Notes: CRA = Compound Remote Associates, AUT = Alternate Uses task, PANAS = Positive and Negative Affect Schedule, BIF = Behavior Identification Form. * $p \leq .05$ (denotes a significant effect of volume condition on performance/score).

problems. A significant difference in performance was not observed with respect to the verbal and spatial problems ($p = .06$). A significant interaction between condition and problem type was not revealed; $F(4, 60) = 0.53, p = .72$.

2.6.3.3 AUT

ANOVAs revealed no significant effect of condition on the degree of fluency, acceptability, or flexibility of responses provided by participants for the AUT; $F(2, 30) = 0.53, p = .59$; $F(2, 30) = 2.23, p = .13$; and $F(2, 30) = 2.38, p = .11$, respectively. A significant effect of condition on originality was found; $F(2, 30) = 4.86, p = .02, \eta^2 = .25$. A Tukey post-hoc test revealed that the responses of participants in the medium volume condition were significantly more original than those of participants in the control condition ($p = .02$). A significant difference in response originality was not observed between the high volume and control conditions ($p = .06$) or the high and medium volume conditions ($p = .99$). With respect to elaboration, Levene's test indicated that the assumption of homogeneity of variances was violated; $F(2, 30) = 5.20, p = .01$. Welch's F-test revealed no significant effect of condition on elaboration; $F(2, 18.58) = 3.10, p = .07$.

2.6.3.4 PANAS

An ANOVA revealed no significant effect of condition on positive or negative affect; $F(2, 30) = 0.72, p = .50$ and $F(2, 30) = 1.61, p = .22$, respectively.

2.6.3.5 BIF

An ANOVA revealed no significant effect of condition on BIF score; $F(2, 30) = 0.72, p = .50$.

2.6.3.6 Likert Scales

2.6.3.6.1 Difficulty

An ANOVA revealed no significant effect of condition on perceived task difficulty for the CRA task, insight problem task, or AUT; $F(2, 30) = 2.49, p = .10$; $F(2, 30) = 0.15, p = .86$; and $F(2, 30) = 2.40, p = .11$, respectively.

2.6.3.6.2 Distraction

An ANOVA revealed a significant effect of condition on perceived level of distraction; $F(2, 30) = 10.99, p < .001, \eta^2 = .42$. Tukey post-hoc tests revealed that participants in the

control condition rated the ambient noise as significantly less distracting than participants in both the medium ($p = .002$) and high ($p < .001$) volume conditions. A significant difference in perceived distraction was not observed between the medium and high volume conditions ($p = .35$).

2.6.3.7 Processing Difficulty Index

An ANOVA revealed a significant effect of condition on perceived processing difficulty; $F(2, 30) = 9.35, p = .001, \eta^2 = .32$. Tukey post-hoc tests revealed that participants in the control condition scored significantly lower on the processing difficulty index than participants in both the medium ($p = .03$) and high ($p < .001$) volume conditions. A significant difference in index score was not observed between participants in the medium and high volume conditions ($p = .09$).

2.6.4 Participants Who Listen to Music While Studying/Working

Analyses were conducted to assess the effect of volume on creative performance for participants who indicated that they do like to listen to music while they study/work. Refer to Table 2.5 for the descriptive statistics associated with the following variables: CRA task performance (overall and divided by item difficulty), insight problem task performance (overall and divided by item type), AUT performance, PANAS scales (for positive and negative affect), BIF score, Likert scales (for perceived task difficulty and level of distraction), and processing difficulty index score.

2.6.4.1 CRA Task

A 3x3 mixed ANOVA was conducted with volume condition as a between-subjects factor and item difficulty as a within-subjects factor. A significant main effect of condition on overall CRA performance was not observed; $F(2, 27) = 1.19, p = .32$. A significant main effect of item difficulty was found; $F(2, 54) = 86.13, p < .001, \eta^2 = .76$. Bonferroni corrected post-hoc tests revealed that participants got significantly more easy difficulty items correct than both medium and hard difficulty items. Participants also got significantly more medium difficulty items correct than hard difficulty items (for all

Table 2.5. Means and standard deviations for each volume condition when variables were analyzed for participants who sometimes like to listen to music while they work/study.

Variable	Condition					
	Control		Medium Volume		High Volume	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Number of Correct CRA Items						
Overall	7.71	3.10	9.00	3.69	9.60	2.50
Easy Items	4.71	1.82	5.67	1.97	5.80	1.69
Medium Items	2.21	1.72	3.00	1.90	2.50	1.08
Hard Items	.79	.70	.33	.52	1.30	1.06
Number of Correct Insight Problems						
Overall*	1.86	.95	2.50	.55	2.90	1.10
Mathematical*	1.29	.73	2.00	.00	1.30	.82
Verbal*	.50	.65	.50	.55	1.10	.57
Spatial*	.07	.27	.00	.00	.50	.53
AUT Performance						
Fluency	21.43	6.36	18.50	8.67	20.40	5.74
Acceptability	12.86	5.55	12.00	6.26	14.70	2.50
Originality	.46	.30	.42	.31	.39	.18
Flexibility	11.14	5.01	10.00	5.51	12.40	1.90
Elaboration	10.43	5.06	8.50	4.76	10.70	4.30
PANAS						
Positive Affect	2.53	.62	3.02	.82	2.59	.64
Negative Affect	1.46	.34	1.52	.51	1.79	.52
BIF						
Construal Level	15.71	5.27	15.67	6.59	13.40	4.74
Likert Scales						
CRA Difficulty	5.00	1.24	5.00	.63	5.70	1.16
Insight Difficulty	4.14	1.23	3.67	1.51	4.60	1.17
AUT Difficulty	4.21	1.48	4.50	1.52	4.70	1.34
Distraction*	2.15 ^a	1.14	4.17	1.60	4.60	1.08
Processing Difficulty Index						
Score*	3.85 ^a	.71	4.33	.83	4.90	.69

Notes: CRA = Compound Remote Associates, AUT = Alternate Uses task, PANAS = Positive and Negative Affect Schedule, BIF = Behavior Identification Form. ^a $n = 13$. * $p \leq .05$ (denotes a significant effect of volume condition on performance/score).

comparisons, $p < .001$). A significant interaction between condition and difficulty was not revealed; $F(4, 54) = 1.07$, $p = .38$.

2.6.4.2 Insight Problem Task

A 3x3 mixed ANOVA was conducted with volume condition as a between-subjects factor and problem type as a within-subjects factor. Levene's test revealed that there was a violation of homogeneity of between-group variance for both mathematical and spatial insight problem performance; $F(2, 27) = 9.93, p = .001$ and $F(2, 27) = 23.33, p < .001$, respectively. Because sample sizes were unequal, a one-way ANOVA was conducted to assess overall insight problem performance across the three conditions (Gardner & Tremblay, 2007). This analysis revealed a significant effect of condition on overall performance; $F(2, 27) = 3.67, p = .04, \eta^2 = .31$. A Tukey post-hoc test found that participants in the high volume condition got significantly more insight problems correct than participants in the control condition ($p = .03$). A significant difference in performance was not observed between the control and medium volume conditions ($p = .36$) or the medium and high volume conditions ($p = .69$). The mixed ANOVA revealed a significant main effect of problem type; $F(2, 54) = 35.93, p < .001, \eta^2 = .57$. Bonferroni corrected post-hoc tests revealed that participants got significantly more mathematical problems correct than both verbal and spatial problems (for both comparisons, $p < .001$). Participants also got significantly more verbal problems correct than spatial problems ($p = .003$). A significant interaction between condition and type was revealed; $F(4, 54) = 2.96, p = .03, \eta^2 = .18$.

With respect to the 2 mathematical insight problems, an independent samples t-test revealed no significant performance difference between the control and high volume conditions; $t(22) = 0.05, p = .97$. When comparing the control and medium volume conditions and the medium and high volume conditions, Levene's test indicated that the assumption of homogeneity of variances was violated; $F(1, 18) = 17.61, p = .001$ and $F(1, 14) = 21.44, p < .001$, respectively. Welch's t-test found that participants in the medium volume condition got significantly more mathematical insight problems correct than participants in both the control and high volume conditions; $t(13) = 3.68, p = .003, d = 1.80$ and $t(9) = 2.69, p = .03, d = 1.39$, respectively.

With respect to the 2 verbal insight problems, independent samples t-tests revealed no significant performance difference between the control and medium volume conditions

or medium and high volume conditions; $t(18) = 0.00, p = 1.00$ and $t(14) = 2.07, p = .06$, respectively. Participants in the high volume condition got significantly more verbal insight problems correct than participants in the control condition; $t(22) = 2.35, p = .03, d = .97$.

With respect to the 2 spatial insight problems, an independent samples t-test revealed no significant performance difference between the control and medium volume conditions; $t(18) = 0.65, p = .53$. Participants in the high volume condition got significantly more spatial insight problems correct than participants in the medium volume condition; $t(14) = 2.29, p = .04, d = 1.18$. When comparing the control and high volume conditions, Levene's test indicated that the assumption of homogeneity of variances was violated; $F(1, 22) = 25.39, p < .001$. Welch's t-test found that participants in the high volume condition got significantly more spatial insight problems correct than participants in the control condition; $t(12.32) = 2.36, p = .04, d = .98$.

2.6.4.3 AUT

ANOVAs revealed no significant effect of condition on the degree of fluency, acceptability, originality, or elaboration of responses provided by participants for the AUT; $F(2, 27) = 0.41, p = .67$; $F(2, 27) = 0.67, p = .52$; $F(2, 27) = 0.21, p = .82$; and $F(2, 27) = 0.45, p = .64$, respectively. With respect to flexibility, Levene's test indicated that the assumption of homogeneity of variances was violated; $F(2, 27) = 4.77, p = .02$. Welch's F-test revealed no significant effect of condition on elaboration; $F(2, 27) = 0.60, p = .56$.

2.6.4.4 PANAS

An ANOVA revealed no significant effect of condition on positive or negative affect; $F(2, 27) = 1.17, p = .33$ and $F(2, 27) = 1.68, p = .21$, respectively.

2.6.4.5 BIF

An ANOVA revealed no significant effect of condition on BIF score; $F(2, 27) = 0.61, p = .55$.

2.6.4.6 Likert Scales

2.6.4.6.1 Difficulty

An ANOVA revealed no significant effect of condition on perceived task difficulty for the CRA task, insight problem task, or AUT; $F(2, 27) = 1.29, p = .29$; $F(2, 27) = 1.04, p = .37$; and $F(2, 27) = 0.34, p = .72$, respectively.

2.6.4.6.2 Distraction

In this group of participants, one (in the control condition) did not provide a response as to how distracting they found the background noise. With respect to the rest of the participants, an ANOVA revealed a significant effect of condition on perceived level of distraction; $F(2, 26) = 12.73, p < .001, \eta^2 = .49$. Tukey post-hoc tests revealed that participants in the control condition rated the ambient noise as significantly less distracting than participants in both the medium ($p = .01$) and high ($p < .001$) volume conditions. A significant difference in perceived distraction was not observed between the medium and high volume conditions ($p = .77$).

2.6.4.7 Processing Difficulty Index

An index score was not computed for the participant who did not provide a response regarding their perceived level of distraction. With respect to the rest of the participants, an ANOVA revealed a significant effect of condition on perceived processing difficulty; $F(2, 26) = 5.92, p = .01, \eta^2 = .32$. Tukey post-hoc tests revealed that participants in the control condition scored significantly lower on the processing difficulty index than participants in the high volume condition ($p = .01$). A significant difference in index score was not observed between the control and medium volume conditions ($p = .38$) or the medium and high volume conditions ($p = .31$).

2.7 Discussion

Mehta et al. (2012) demonstrated that creative performance could be enhanced by moderate volumes of ambient noise, relative to both low and high volumes of noise. They also suggested that the effects of noise on creativity were related to noise-induced changes in processing difficulty and cognitive abstraction. Consequently, it was expected

that participants in the medium volume condition would perform significantly better than participants in the control and high volume conditions on all three creativity tasks. Furthermore, it was predicted that the noise conditions would be associated with higher levels of cognitive abstraction and processing difficulty, relative to the control condition.

2.7.1 All Participants

Initial results from this study revealed that overall performance was not affected by volume for any of the three creativity tasks considered; however, some effects were observed when more specific aspects of the tasks were examined. In particular, participants in the medium volume condition answered more medium difficulty CRA items correct than participants in the high volume condition. As in Isen et al. (1987), participants generally got most of the easy CRA items correct and most of the hard CRA items incorrect. Ceiling and floor effects, therefore, may explain why an effect of volume was not observed with respect to performance on the easy or hard difficulty items.

Although volume was found to affect performance on some of the CRA items, an effect was not observed for performance on the insight problem task or AUT. As discussed, the CRA and insight problem task are measures of convergent creativity and the AUT is a measure of divergent creativity. Mehta et al. (2012) found an effect of volume on a number of divergent thinking tasks, so it seems unlikely that noise has no effect on divergent thinking. Instead, results from this study may be interpreted as suggesting that noise affects convergent thinking to a greater degree than divergent thinking. Though noise did not impact performance on the insight problem task, participants demonstrated differential performance on the mathematical, verbal, and spatial problems. This provides evidence for an empirical difference among the three main types of insight problems identified by Dow and Mayer (2004).

These initial results from Study 1 provide weak support for Mehta et al.'s (2012) conclusion that creativity is enhanced by moderate volumes of noise. One possibility as to why stronger effects were not found is that the noise manipulation did not enhance cognitive abstraction. Mehta et al. suggested that moderate volumes of noise enhance creativity indirectly by increasing processing difficulty and abstraction. In this study, a

positive relationship was observed between volume and perceived processing difficulty, but a subsequent increase in cognitive abstraction did not occur. It is unclear why abstraction was not affected by volume, particularly since Mehta et al. found a significant effect of noise on BIF score; nevertheless, this lack of effect may explain why a performance difference was not observed between the control and medium volume conditions.

When all participants were considered together, the only significant difference in performance that occurred was between participants in the medium and high volume conditions. Mehta et al. (2012) proposed that creative performance begins to decline once ambient noise reaches a certain volume due to a reduction in information processing. This may explain why participants in the high volume condition performed worse on some of the CRA items than participants in the medium volume condition. Negative mood may also have contributed to this performance discrepancy. Compared to the control condition, the high volume condition was found to be associated with a significantly higher level of negative affect. Negative affect has been shown to increase the perceived volume of a sound (Siegel and Stefanucci, 2011). Consequently, the high volume condition may have been perceived by participants as louder than it was, effectively amplifying the degree to which processing abilities and performance were impaired.

2.7.2 Participants Divided by Study/Work Preferences

Preliminary analyses in this study suggested that medium volumes of ambient noise were associated with enhanced performance on one aspect of the CRA task. When individual differences in study and work preference were taken into account though, a much more nuanced pattern of results emerged.

2.7.2.1 Summary of Significant Results

Across all three groups, the pattern of ratings regarding perceived distraction was consistent: the medium and high volume conditions were both rated as equivalent to one another and as more distracting than the control condition.

For participants who prefer to work without music, increased levels of distraction were not associated with noise-related variations in creative performance; instead, both the medium and high volume conditions were associated with significantly higher levels of negative affect than the control condition. Scores on the processing difficulty index were also found to be higher for those in the high volume condition than those in the control condition; a difference in scores was not observed, however, between the control and medium volume conditions or between the medium and high volume conditions.

For participants who sometimes like to work with music, an effect of volume on performance was observed for the AUT. Specifically, participants in the medium volume condition produced AUT responses that were more original than those of participants in the control condition. For this group of participants, scores on the processing difficulty index were lowest among those in the control condition and equivalent for those in the medium and high volume conditions.

For participants who prefer to work with music, an effect of volume on performance was observed for the insight problem task. Specifically, compared to participants in the control condition, participants in the high volume condition got more problems correct overall. Participants in the high volume condition also got more verbal and spatial problems correct than participants in the control condition and more spatial problems correct than participants in the medium volume condition. Participants in the medium volume condition got more mathematical problems correct than participants in both the control and high volume conditions. For this group of participants, the high volume condition was associated with higher scores on the processing difficulty index than the control condition; a difference in scores was not observed between the control and medium or medium and high volume conditions.

2.7.2.2 Discussion of Results across Groups

Overall, these results suggest that participants who, at least sometimes, work or study with music benefit from the presence of noise. Specifically, the addition of noise was associated with notable improvements in the insight problem task and AUT for

participants who indicated that they like to work with music and participants who sometimes like to work with music, respectively.

Many of the occasional listeners indicated that when they did listen to music while working, it was while working on tasks such as problem solving. It was unexpected, therefore, that these participants would show improved performance on the AUT and not on the insight problem task. However, a number of individuals also indicated that when they did listen to music, it was often instrumental. Although unintelligible, speech was included in the audio stimulus implemented in this study. Consequently, the presence of speech may have been too distracting for these participants to solve problems as effectively as they normally would have in the presence of non-speech-based noise. Because the AUT does not require the production of a single answer, participants may have found that it required less concentration than the insight problem task. This may be why a performance deficit was not observed in the presence of noise with respect to the AUT; still, it remains unclear why some participants actually benefited from the addition of background noise.

Although higher volumes of noise were related to higher scores on the processing difficulty index, no effect of noise on cognitive abstraction was observed. Therefore, it does not seem as though Mehta et al.'s (2012) proposed model, regarding noise, processing difficulty, abstraction, and creativity, can explain this data. Two alternative possibilities are proposed. The first is that participants eventually began to ignore the noise and it became a motivating factor that allowed participants to “zone in” on the task at hand; this explanation seems plausible, considering the ways in which white noise has been shown to benefit certain aspects of cognition (as discussed in Chapter 1). The second is that the noise distracted participants to an extent that prevented them from fully concentrating and, consequently, “overthinking” the tasks; the resulting mental “relaxation” may have allowed participants to think more freely and, thus, creatively. Unfortunately, the data from this study does not allow either of these proposed explanations to be examined; further research in this area is necessary.

2.7.3 Discrepancies between Study 1 and the Work of Mehta et al.

The finding that cognitive abstraction was not affected by volume is one discrepancy between this study and that of Mehta et al. (2012). Another difference between the two studies is that optimal performance in Study 1 was not always found to occur in the medium volume condition, as was suggested by Mehta et al. These disparities may be due to differences in the experimental setup of the auditory stimuli.

In this study, for instance, participants were seated at desks which were parallel to the table on which the speakers were placed. Mehta et al. sat participants at desks which were placed in a semicircle, equidistant from a set of speakers located in the center of the circle. Additionally, Mehta et al. do not indicate what brand of speakers or sound meter they used. It is possible, therefore, that the audio equipment used by Mehta et al. was of a different quality than what was used in this study.

The sound Mehta et al. used was recorded by the researchers from a cafeteria, roadside, and construction site. The recorded noises were electronically combined, and the resulting audio track was played at 70 and 85 dB (± 3 dB as a result of the dynamic nature of the audio) for the medium and high volume conditions, respectively. This study attempted to recreate these volume conditions using coffee shop sounds streamed from a website; due to volume fluctuations in the audio, however, the actual volumes of the medium and high volume conditions in this study were approximately 67 and 81 dB, respectively. Sound level, as measured in decibels, does not correlate directly to perceived loudness. On the contrary, perceived volume effectively doubles with every increase of 9 dB (Stevens, 1972). Perhaps, therefore, the high volume condition in this study was perceptually more similar to Mehta et al.'s medium volume condition than their high volume condition. In fact, results from this study suggest that participants in the medium volume condition found the noise to be just as distracting as those in the high volume condition. This suggests that the medium and high volume conditions were not perceptually different from one another.

In general, Mehta et al.'s experimental setup may have been more controlled and precise than that of this study; alternatively, their results may not be as robust as was assumed.

Regardless of why different results were obtained, however, the conclusions of this study should not be viewed as incongruous with those of Mehta et al.

2.7.4 Conclusions

Importantly, under no circumstances did participants in the control condition perform better on any of the tasks than participants in either of the noise conditions. Instead, it should be acknowledged that noise generally had a beneficial effect on creative performance. Even for participants who typically work without music, the noise did not impede creativity; instead, the noise manipulation appears to have done nothing but put them in a bad mood. This may have occurred because they are accustomed to working in quiet environments and, thus, found the noise to be irritating. Similarly, participants who often work with music may have benefited from the noise manipulation because it evoked memories of their usual work environment. Based on the work of Söderlund et al. (2010) though, it seems possible that differences in preferred ambient environments are initially due to physiological factors.

Söderlund et al. (2010) found that the presentation of white noise improved attention for children who had previously been classified as inattentive, but distracted those who had been labeled as attentive. Referring to the moderate brain arousal model (Sikström & Söderlund, 2007), they proposed that these differential effects of noise on attention were related to differences in dopamine levels within the brain. Specifically, the moderate brain arousal model suggests that a hypodopaminergic brain will benefit from the addition of input noise because it may allow for a distinction between random and task-related neural firing. For typical or hyperdopaminergic brains, however, the addition of noise may overwhelm the system and cause a decline in performance. Perhaps, individuals are drawn to environments which will enhance their neural processing (i.e. hypodopaminergic individuals will seek out noisy environments while hyperdopaminergic individuals will avoid them). Consequently, it may be that the individuals who benefited from the presentation of noise in this study have lower levels of dopamine than those who did not benefit from the noise. Regardless of whether or not this is true, it remains that the relationship between ambient noise and creativity was

moderated by differences in preferred work environments. Future research regarding noise and cognition should, therefore, consider the effects of individual differences.

Chapter 3

3 Study 2

Study 1 demonstrated that some aspects of creativity can be enhanced by the presence of ambient noise. The beneficial effects of noise on creativity were particularly apparent for individuals who typically listen to music while they work; noise was not found to have an effect on the creative performance of individuals who never work with music. Study 1 also found a positive relationship between noise and perceived processing difficulty, but an effect of noise on cognitive abstraction was not observed. Overall, therefore, Study 1 provides some support for the work of Mehta et al. (2012). It appears that moderate to high volumes of ambient noise may enhance creativity, although it is unclear whether this effect is driven by increases in processing difficulty and abstraction, as was suggested.

Another goal of this thesis was to investigate the effects of ambient noise on cognitive flexibility. Cognitive flexibility is a feature of executive functioning that supports diverse thinking and problem solving (Spiro et al., 1988). It has also been suggested that cognitive flexibility is related to creativity (Murray, Sujan, Hirt, and Sujan, 1990). Although the relationship between them is not entirely understood, cognitive flexibility and creativity likely share many of the same core cognitive processes; parallels between these concepts may be drawn from the literature, and diverse thinking is a key component of both cognitive flexibility (Spiro et al., 1988) and creativity (Guilford, 1957). Given that ambient noise may enhance creativity, it seems likely that cognitive flexibility will also be enhanced by ambient noise. Study 2 was designed to assess this possibility.

3.1 Measuring Cognitive Flexibility

Cognitive flexibility is believed to play a role in problem solving and learning, specifically by supporting the identification and testing of strategies and rules (Spiro et al., 1988). As discussed in Chapter 1, Section 1.2, category learning is a behaviour which may benefit from cognitive flexibility. The COmpetition between Verbal and Implicit Systems (COVIS; Ashby, Alfonso-Reese, Turken, & Waldron, 1998) theory makes specific predictions regarding category learning and cognitive flexibility, and how they

may interact. According to COVIS, overt hypothesis testing is executed by a primary, explicit learning system which relies on working memory and executive control. COVIS also predicts the existence of a secondary, implicit learning system which employs associative processes to gradually learn procedural-based responses. The two systems compete during learning to produce the correct response; however, they may also be viewed as complementary, with learning being shifted to the implicit system if the explicit system fails to provide satisfactory performance.

Because it supports rule-based learning, the explicit learning system is believed to be more influenced by cognitive flexibility than the implicit learning system. This conclusion has been supported by neurological imaging. Cognitive flexibility is associated with brain regions such as the prefrontal cortex, but not the basal ganglia (Barbey, Colom, & Grafman, 2013): areas associated with the explicit and implicit systems, respectively (Ashby, et al., 1998). Due to the differential role that it plays in each system, cognitive flexibility can be studied using tasks which distinguish between explicit and implicit learning. Categorization tasks involving rule-defined (RD) and information integration (II) category sets provide one way in which this may be accomplished.

Typically, in RD category sets, a single feature may be used to distinguish members of one category from another. Consequently, the items in RD category sets can be categorized using a simple, well-defined rule. In contrast, II category sets require that multiple features be considered during categorization. Learning II categories, therefore, relies on a feature integration strategy (i.e. information integration) which is acquired through repetition and reinforcement. As a result, it is often difficult to verbalize the strategy which is applied during the learning of II category sets. Given that RD categorization involves verbalizeable rules and II categorization does not, RD and II categorization rely on the explicit and implicit learning systems, respectively (Ashby et al., 2011). Accordingly, RD category learning is more influenced by cognitive flexibility than II category learning. Factors that affect cognitive flexibility, therefore, will have a greater impact on performance of RD categorization than II categorization.

3.2 Purpose and Hypotheses

The purpose of Study 2 was to investigate the effect that ambient noise has on cognitive flexibility as it relates to category learning. Performance on an RD vs. II categorization task was compared across three conditions: control, medium volume noise, and high volume noise. Based on the results of Mehta et al. (2012) and Study 1, an effect of noise on cognitive flexibility was expected to be found.

In Study 1, participants rated the medium and high volume conditions as perceptually similar to one another. Study 2 implemented the same experimental setup as Study 1. Therefore, the following predictions were made: (1) performance on RD categorization would be equivalent for participants in the medium and high volume conditions; (2) performance on RD categorization would be higher for participants in the medium and/or high volume conditions and lowest for participants in the control condition; and (3) a beneficial effect of volume on II categorization would not be observed. A differential effect of noise on RD and II performance would suggest that the noise was affecting cognitive flexibility, as opposed to category learning in general. Results such as these would also provide support for the application of multiple systems theories, such as COVIS, in the study of categorization. Given that an effect of noise on creativity was found to be more apparent for those who typically work with music, any effects of noise on category learning were also expected to be similarly moderated.

3.3 Method

3.3.1 Participants

A total of 180 undergraduate students from the University of Western Ontario participated in this study. All participants had normal, or corrected to normal, hearing and visual acuity, and spoke English as a first language. Participants were recruited through the Western Psychology Research Participation Pool, and received course credit for their participation.

3.3.2 Materials

3.3.2.1 Category Learning Task

The category learning task used in this study was adapted from Miles and Minda (2011). Both category sets consisted of Gabor patches (i.e. sine wave gratings) characterized by variations in the spatial frequency and orientation of alternating light and dark bands. For the RD category set, spatial frequency was selected as the critical attribute by which category membership was defined. For the II category set, category membership was defined by a combination of frequency and orientation. For each category set, two multivariate normal distributions were designed using the parameters outlined in Table 3.1: one representing Category A and the other, Category B. From each distribution, 40 values were randomly sampled and PsychoPy (Peirce, 2007) software was used to generate a Gabor patch based on the coordinates of each of the sampled values. For all values, the sine wave grating frequency was calculated as $f = .25 + (\chi_f/50)$ cycles per gradient, and orientation was calculated as $o = \chi_o(.36^\circ)$. Each Gabor patch was made to resemble a crystal ball by adding two solid lines to the bottom.

Table 3.1. Parameters of the distributions used to generate items for the RD and II category sets.

Parameters					
Category	μ_f	μ_o	σ_f^2	σ_o^2	$\text{cov}_{f,o}$
RD Category Set					
Category A	280	125	75	9,000	0
Category B	320	125	75	9,000	0
II Category Set					
Category A	268	157	4,538	4,538	4,351
Category B	332	93	4,538	4,538	4,351

Notes: RD = rule-defined, II = information integration, f = frequency, o = orientation. Dimensions are in arbitrary units.

Examples of the Gabor patches, and the distributions from which they were sampled, are displayed in Figure 3.1. The solid lines displayed in Figures 3.1a and 3.1b represent the optimal decision boundary for the RD and II category sets, respectively. As depicted in Figure 3.1a, spatial frequency is the critical attribute for the RD category set. Items with lower spatial frequency (i.e. items to the left of the line) are members of Category A and items with higher spatial frequency belong to Category B. As displayed in Figure 3.1b,

the optimal decision boundary for the II category set lies diagonally within the distribution space; consequently, both frequency and orientation must be considered during categorization. In this case, items that fall above the line belong to Category A and items that fall below the line belong to Category B. A total of 160 items were generated: 40 from Category A of the RD set, 40 from Category B of the RD set, 40 from Category A of the II set, and 40 from Category B of the II set.

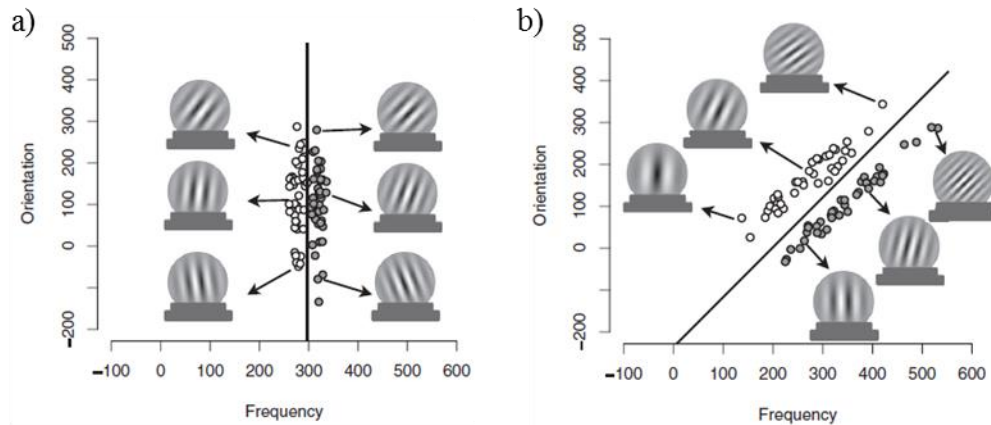


Figure 3.1. Examples of the Gabor patch stimuli used in Study 2. Items from categories A and B are represented by the light and dark circles, respectively. The solid lines represent optimal decision boundaries between the two categories. The units of each dimension are arbitrary. a) The distribution from which the rule-defined category set was derived. Frequency is the critical attribute. b) The distribution from which the information integration category set was derived. Both frequency and orientation determine category membership.

3.3.2.2 Auditory stimulus

Refer to Chapter 2, Section 2.5.2.4, for a description of the auditory stimulus and setup used in this study. The actual volumes for the three conditions, averaged across all readings, were approximately 33 dB, 68 dB, and 82 dB for the control, medium, and high volume conditions, respectively.

3.3.2.3 Follow-up questionnaires

Refer to Chapter 2, Section 2.5.2.5, for a description of the follow-up questionnaires completed by participants during this study.

3.3.3 Procedure

Participants were tested in pairs. Each pair of participants was randomly assigned to one of the three volume conditions: control ($n = 60$), medium volume noise ($n = 60$), or high volume noise ($n = 60$). These conditions were prepared before participants arrived in the lab. Participants were also randomly assigned to one of the two category set conditions: RD ($n = 88$) or II ($n = 92$). This study, therefore, consisted of six conditions: control RD ($n = 30$), medium volume RD ($n = 30$), high volume RD ($n = 28$), control II ($n = 30$), medium volume II ($n = 30$), and high volume II ($n = 32$). The same procedure was used for all participants, regardless of condition.

After providing informed consent, participants were given a verbal explanation of the category learning task. Specifically, participants were told that they would be shown images of crystal balls and they were to indicate, by button press, if the balls belonged to a blue wizard or a green wizard. They were told that they would not be given any instructions regarding how to make these categorization judgements; instead, they would be provided with feedback after each trial and, by relying on this feedback, they should eventually learn how to complete the task. Participants were then seated at computers and, if they had been assigned to the medium or high volume conditions, the speakers were turned on. If participants were in the control condition, the speakers were left off.

Participants completed the task on Macintosh computers. On each trial, a single Gabor patch was presented in the center of the computer screen. A blue and a green wizard were depicted on the left and right sides of the screen, respectively. The “1” key on the computer keyboard was covered by a blue sticker and the “0” key was covered by a green sticker. Participants indicated by button press whether the displayed Gabor patch belonged to the blue wizard (i.e. Category A) or the green wizard (i.e. Category B). After each trial, participants were provided with visual feedback in the form of the words “correct” or “incorrect” if their response was correct or incorrect, respectively. All 80 generated items (40 per category) were presented for a total of 80 trials in one block. The order of these items was randomized for each block and each participant. This procedure was repeated for a total of 320 trials divided into four, uninterrupted blocks. Once the categorization task was complete, the background noise (if present) was shut off.

Participants then completed the follow-up questionnaire via paper and pencil. (Refer to Figure 3.2 for a visual depiction of the task procedure.)

3.3.4 Data Cleaning

One participant (in the medium volume II condition) fell asleep during the study. This participant's data was not analyzed.

3.4 Results

Analyses were first conducted to assess the effects of volume on category learning performance for all participants. Performance on both RD and II category sets was quantified as the proportion of correct items achieved by each participant. For each set, overall performance, as well as performance during each of the four blocks, was compared across the three volume conditions. Analyses were also completed to compare positive affect, negative affect, BIF score, perceived task difficulty, level of distraction, and perceived processing difficulty across the volume and category set conditions. Tables 3.2 and 3.3 present the descriptive statistics associated with the analyses for participants in the RD and II conditions, respectively.

3.4.1 Category Learning Performance

A 2x3x4 mixed ANOVA was conducted with category set condition and volume condition as between-subjects factors and block as a within-subjects factor. Levene's test revealed that there was a violation of homogeneity of between-group variance for performance during blocks 1, 2, and 3; $F(5, 173) = 8.48, p < .001$; $F(5, 173) = 6.22, p < .001$; and $F(5, 173) = 4.48, p = .001$, respectively. Because sample sizes were unequal, one-way ANOVAs were conducted to assess overall category learning performance across the two category set conditions and across the three noise conditions (Gardner & Tremblay, 2007). With respect to category set condition, Levene's test revealed a violation of homogeneity; $F(1, 177) = 15.85, p < .001$. Welch's F-test revealed that participants in the RD category set condition performed significantly better than participants in the II category set condition; $F(1, 147.92) = 23.93, p < .001, \eta^2 = .14$. A

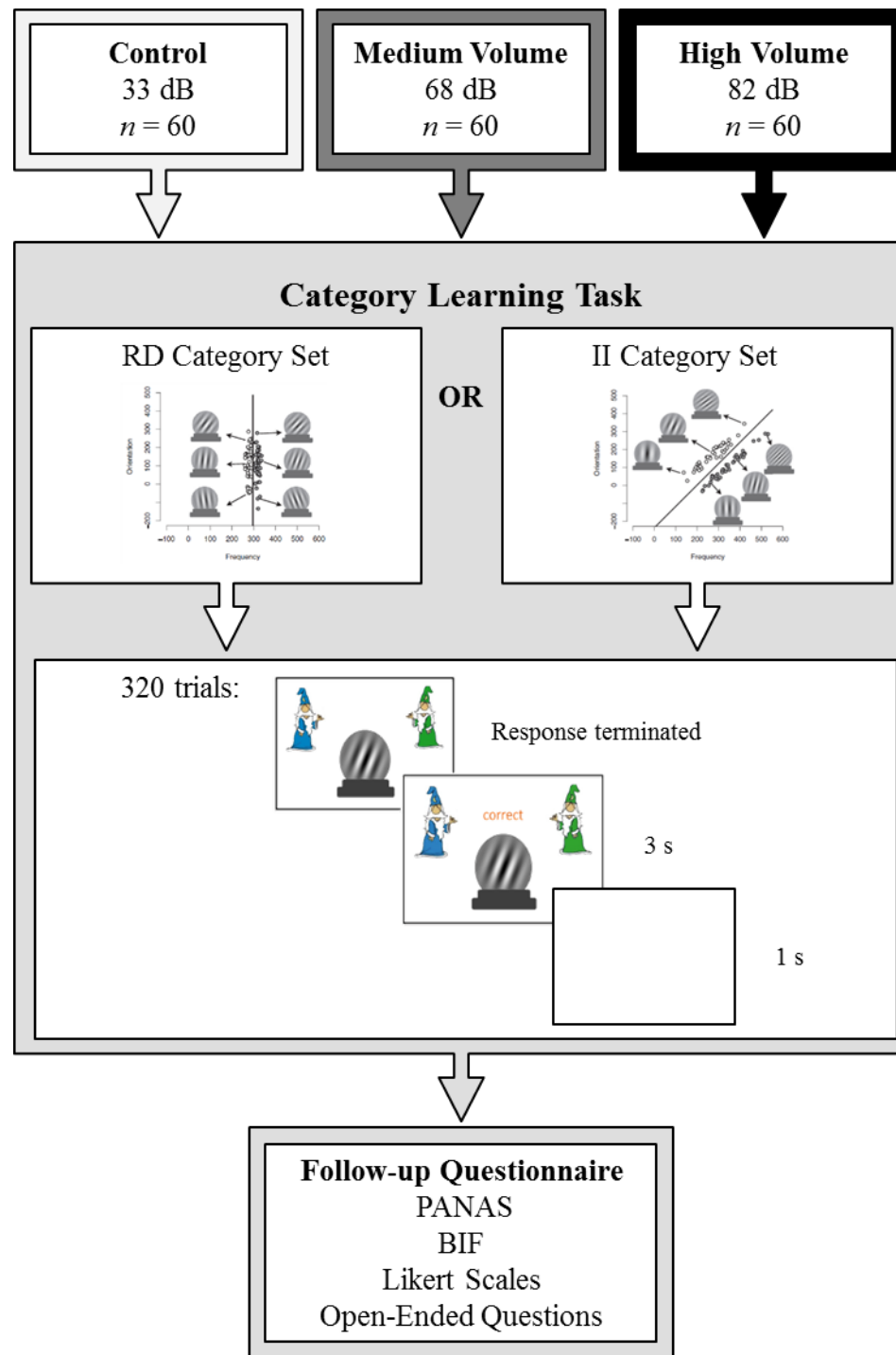


Figure 3.2. Experimental procedure for Study 2. Participants were assigned to one of three volume conditions and one of two category set conditions. Participants completed either the rule-defined or information integration category learning task, followed by a four-part questionnaire.

Table 3.2. Means and standard deviations for the analyses associated with each volume condition for all participants who completed the RD category set.

Variable	Condition					
	Control		Medium Volume		High Volume	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Category Learning Performance						
Overall	.73	.14	.75	.14	.76	.12
Block 1	.64	.15	.65	.16	.65	.13
Block 2	.74	.15	.76	.16	.76	.14
Block 3	.76	.17	.78	.17	.80	.14
Block 4	.79	.15	.81	.16	.82	.13
PANAS						
Positive Affect	2.11	.67	1.95	.64	1.96	.72
Negative Affect	1.59	.51	1.60	.50	1.66	.44
BIF						
Construal Level	15.10	5.81	15.07	5.32	15.57	4.69
Likert Scales						
Difficulty	3.43	1.55	3.13	1.53	3.43	1.73
Distraction*	1.70	1.24	2.97	1.77	3.64	1.70
Processing Difficulty Index						
Score*	2.57	1.08	3.05	1.28	3.54	1.35

Notes: RD = rule-defined, PANAS = Positive and Negative Affect Schedule, BIF = Behavior Identification Form. * $p \leq .05$ (denotes a significant effect of volume condition on performance/score).

significant main effect of volume condition was not found; $F(2, 176) = 0.48, p = .62$.

One-way ANOVAs were also conducted to test for an interaction between category set condition and volume condition. A significant effect of volume condition on performance was not found for either category set when the RD and II conditions were considered separately; $F(2, 85) = 0.27, p = .76$ and $F(2, 88) = 0.56, p = .58$, respectively. The Greenhouse-Geisser correction ($\epsilon = .69$) was applied to the within-subjects analysis of the mixed ANOVA because Mauchley's Test of Sphericity was found to be significant; $X^2(5) = 110.67, p < .001$. A significant main effect of block was found; $F(2.08, 359.77) = 92.51, p < .001, \eta^2 = .35$. A significant interaction between block and category set condition was also found; $F(2.08, 359.77) = 5.87, p = .003, \eta^2 = .03$. With respect to the RD condition, Tukey post-hoc tests (conducted by calculating and assessing q-statistics) revealed the following: performance was significantly worse during block 1 than during all other blocks (for all comparisons, $p < .001$), significantly worse during block 2 than

Table 3.3. Means and standard deviations for the analyses associated with each volume condition for all participants who completed the II category set.

Variable	Condition					
	Control		Medium Volume		High Volume	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Category Learning Performance						
Overall	.65	.08	.68	.10	.66	.08
Block 1	.61	.07	.60	.10	.61	.08
Block 2	.65	.07	.69	.10	.65	.09
Block 3	.67	.10	.72	.11	.70	.11
Block 4	.68	.13	.71	.13	.70	.13
PANAS						
Positive Affect	2.01 ^a	.71	2.02	.62	2.17	.76
Negative Affect	1.48 ^a	.38	1.62	.56	1.68	.48
BIF						
Construal Level	14.27	5.23	14.66	5.37	14.91	5.49
Likert Scales						
Difficulty	4.33 ^b	1.54	4.32	1.28	4.25	1.37
Distraction*	1.43	.73	3.59	1.45	3.75	1.70
Processing Difficulty Index						
Score*	2.88 ^b	.86	3.95	1.10	4.00	1.21

Notes: II = information integration, PANAS = Positive and Negative Affect Schedule, BIF = Behavior Identification Form. ^a $n = 31$. ^b $n = 29$. * $p \leq .05$ (denotes a significant effect of volume condition on performance/score).

during block 4 ($p < .01$), and equivalent during blocks 2 and 3 and blocks 3 and 4 (for both comparisons, $p > .05$). With respect to the II condition, Tukey post-hoc tests revealed the following: performance was significantly worse during block 1 than during all other blocks (for all comparisons, $p < .001$), significantly worse during block 2 than during block 3 ($p < .05$), and equivalent during blocks 2 and 4 and blocks 3 and 4 (for both comparisons, $p > .05$). A significant interaction between block and volume condition was not revealed; $F(4.16, 359.77) = 0.96$, $p = .44$. The three-way interaction between block, category set condition, and volume condition was not significant; $F(4.16, 359.77) = 0.38$, $p = .83$.

3.4.2 PANAS

One participant (in the high volume II condition) did not complete the PANAS.

3.4.2.1 Positive Affect

A 2x3 ANOVA revealed no significant main effect of category set condition or volume condition on positive affect; $F(1, 172) = 0.33, p = .57$ and $F(2, 172) = 0.25, p = .78$, respectively. A significant interaction between category set and volume condition was not revealed; $F(2, 172) = 0.75, p = .47$.

3.4.2.2 Negative Affect

A 2x3 ANOVA revealed no significant main effect of category set condition or volume condition on negative affect; $F(1, 172) = 0.09, p = .76$ and $F(2, 172) = 1.09, p = .34$, respectively. A significant interaction between category set and volume condition was not revealed; $F(2, 172) = 0.34, p = .71$.

3.4.3 BIF

A 2x3 ANOVA revealed no significant main effect of category set condition or volume condition on BIF score; $F(1, 173) = 0.64, p = .43$ and $F(2, 173) = 0.17, p = .85$, respectively. A significant interaction between category set and volume condition was not revealed; $F(2, 173) = 0.02, p = .98$.

3.4.4 Likert Scales

3.4.4.1 Difficulty

One participant (in the medium volume II condition) did not provide a response as to how difficult they found the task. With respect to the rest of the participants, a 2x3 ANOVA revealed that participants in the II category set condition rated the task as significantly more difficult than participants in the RD condition; $F(1, 172) = 18.49, p < .001, \eta^2 = .10$. A significant main effect of volume condition was not found; $F(2, 172) = 0.17, p = .85$. A significant interaction between category set and volume condition was not revealed; $F(2, 172) = 0.24, p = .79$.

3.4.4.2 Distraction

A 2x3 ANOVA was conducted. Levene's test indicated that the assumption of homogeneity of variances was violated; $F(5, 173) = 5.22, p < .001$. Because sample sizes

were unequal, one-way ANOVAs were conducted to assess perceived level of distraction across the two category set conditions and across the three noise conditions (Gardner & Tremblay, 2007). A significant main effect of category set condition was not found; $F(1, 177) = 0.50, p = .48$. With respect to volume condition, Levene's test revealed a violation of homogeneity; $F(2, 176) = 13.07, p < .001$. Welch's F-test revealed a significant effect of volume condition on perceived level of distraction; $F(2, 109.87) = 46.02, p < .001, \eta^2 = .63$. Games-Howell post-hoc tests revealed that participants in the control condition rated the ambient noise as significantly less distracting than participants in both the medium and high volume conditions (for both comparisons, $p < .001$). A significant difference in perceived distraction was not observed between the medium and high volume conditions ($p = .34$). One-way ANOVAs were also conducted to assess the effects of volume on perceived distraction for each of the category set conditions separately. Results from these analyses were consistent with the pattern of results associated with the main effect of volume. This suggests that there was no interaction between the category set and volume conditions with respect to perceived distraction.

3.4.5 Processing Difficulty Index

An index score was not computed for the participant who did not provide a response regarding task difficulty. With respect to the rest of the participants, a 2x3 ANOVA revealed that participants in the II category set condition scored significantly higher on the processing difficulty index than participants in the RD condition; $F(1, 172) = 10.38, p = .002, \eta^2 = .06$. A significant main effect of volume condition was found; $F(2, 172) = 13.11, p < .001, \eta^2 = .13$. Bonferroni corrected post-hoc tests revealed that participants in the control condition scored significantly lower on the index than participants in both the medium ($p = .001$) and high ($p < .001$) volume conditions. A significant difference in index scores was not observed between the medium and high volume conditions ($p = .62$). A significant interaction between category set and volume condition was not revealed; $F(2, 172) = 1.00, p = .37$.

3.4.6 Strategy Analysis

To gain further insight into how participants completed the task, a strategy analysis was completed. This analysis was adapted from work by Miles, Matsuki, and Minda (2014) and Minda and Rabi (2015), and was based on general recognition theory (GRT).

According to GRT, objects may be mentally represented as points in perceptual space. Categories of objects are separated by decision boundaries which split the perceptual space into different regions. Categorization judgments, therefore, involve identifying the correct decision boundary and deciding which region of space an object belongs to (Ashby & Gott, 1988). The placement of the decision boundary is dependent upon which strategy is used. Consider, for instance, the RD category set presented in Figure 3.1a. The decision boundary which correctly divides categories A and B in this category set represents a frequency-based strategy. Applying an orientation-based strategy would result in a horizontal decision boundary, which would be inappropriate for dividing items into Category A or B. Ultimately, categorization strategies may be estimated by identifying potential decision boundaries.

In this strategy analysis, models were used to compare participants' given responses with the responses they would have made if they had used a particular strategy. Five decision-bound models were fit to the data of each participant for each block of the category learning task: a frequency-based model, which estimated the correct decision boundary for the RD category set; an orientation-based model, which estimated a horizontally placed decision boundary based on an incorrect rule-based strategy; an II model, which estimated the correct decision boundary for the II category set; a guessing model, which estimated random responding of "blue" or "green," with equal probabilities for each response; and a guessing model which estimated random responding with unequal probabilities for each response. Models were fit to the data by maximizing the log likelihood and model comparisons were completed using the Akaike information criterion (AIC). The proportion of participants in each condition who were fit by each model is presented in Table 3.5. Note that the guessing models were combined (i.e. the proportion of participants fit by each guessing model at each block was summed).

Learning of the II category set generally appears to have occurred at a slower rate than that of the RD set; because II categorization relies on gradual, associative-based learning, this was anticipated. For both category sets, participants are expected to acquire the appropriate strategies via a guess-and-check method. It is not surprising, therefore, that many participants appear to have been using a guessing strategy during block 1. The proportion of participants using a guessing strategy generally declined over the course of the task, although some participants in the noise conditions seem to have returned to guessing during the final block. Some participants who completed the II category set also seem to have switched to using an orientation-based strategy during the latter portion of the task. This shift in strategies among participants in the medium and high volume conditions may have occurred because they were overwhelmed by the noise and their ability to focus and consistently apply the correct strategy was, thus, reduced. Overall, however, it appears as though participants in the noise conditions began to employ the correct strategies at an earlier point during the task than participants in the control condition. During the first two blocks of the task, the majority of participants using the optimal strategy were in the high volume condition. Furthermore, among those who completed the RD category set, the frequency-based strategy was consistently employed by more participants in the high volume condition than participants in either the control or medium volume conditions.

Table 3.4. Proportion of all participants in each condition who were fit by each of the four models.

Block	Model											
	Guessing			II			Frequency Rule			Orientation Rule		
	Control	Medium	High	Control	Medium	High	Control	Medium	High	Control	Medium	High
RD Category Set												
1	.40	.47	.32	.00	.00	.04	.60	.53	.64	.00	.00	.00
2	.20	.20	.14	.00	.03	.00	.80	.77	.86	.00	.00	.00
3	.23	.13	.07	.00	.00	.04	.77	.77	.86	.00	.10	.04
4	.17	.20	.14	.00	.00	.00	.83	.80	.86	.00	.00	.00
II Category Set												
1	.27	.34	.34	.47	.41	.50	.10	.10	.03	.17	.14	.13
2	.20	.17	.16	.57	.66	.75	.00	.00	.00	.23	.17	.01
3	.13	.10	.06	.80	.79	.78	.00	.03	.03	.07	.07	.13
4	.17	.24	.22	.73	.76	.63	.00	.00	.00	.10	.00	.16

Notes: II = information integration, RD = rule-defined. The frequency rule model represents the optimal strategy for categorizing the RD items (emphasized by the bolded box in the top half of the table). The II model represents the optimal strategy for categorizing the II items (emphasized by the bolded box in the bottom half of the table).

3.4.7 Preference for Studying or Working with Music

In response to the first open-ended question, 68 participants stated that they do not like to listen to music while studying or working, 37 indicated that they occasionally like to listen to music while studying or working, and 72 stated they do like to listen to music while studying or working. Two participants (one in the control II condition and one in the high volume II condition) did not provide a response to this question. Table 3.4 depicts the spread of participants, who did respond, across the six conditions based on their study/work preferences. As in Study 1, the data was divided based on study/work preferences and all analyses in Section 3.4 were repeated for each subgroup. A significant effect of volume condition with respect to category learning performance was not observed for any of the three subgroups considered. These analyses, therefore, are not considered further.

Table 3.5. Participants divided by category condition, volume condition, and their stated preference for listening to music while they study/work.

Like to Study/Work with Music	Volume Condition		
	Control	Medium	High
RD Category Set Condition			
No	<i>n</i> = 12	<i>n</i> = 11	<i>n</i> = 9
Sometimes	<i>n</i> = 6	<i>n</i> = 10	<i>n</i> = 6
Yes	<i>n</i> = 12	<i>n</i> = 9	<i>n</i> = 13
II Category Set Condition			
No	<i>n</i> = 9	<i>n</i> = 11	<i>n</i> = 16
Sometimes	<i>n</i> = 2	<i>n</i> = 8	<i>n</i> = 5
Yes	<i>n</i> = 18	<i>n</i> = 10	<i>n</i> = 10

Notes: RD = rule-defined, II = information integration.

3.5 Discussion

The purpose of this study was to investigate the relationship between ambient noise and cognitive flexibility in a learning-based task. Based on findings from Study 1, it was predicted that cognitive flexibility would be enhanced by ambient noise. It was expected, therefore, that the presence of noise would be associated with optimal performance on an RD category learning task and performance on an II category learning task would be unaffected. As expected, II category learning was unrelated to volume condition.

Additionally, however, no relationship was observed between noise and RD categorization performance. These findings suggest that ambient noise does not affect cognitive flexibility.

The expectation that RD category learning would be enhanced by noise was based largely on the assumption that cognitive flexibility may rely on some of the same cognitive mechanisms as creativity. Diverse thinking is a hallmark characteristic of both cognitive flexibility (Spiro et al., 1988) and creativity (Guilford, 1957), and research has found that these concepts are similarly affected by neurological stress (Ghacibeh, et al., 2006) and mood (Isen et al., 1987; Nadler et al., 2010). Both cognitive flexibility and creativity refer to broad forms of cognition and, as such, it is difficult to definitively identify the neurological basis of either. Research appears to suggest though, that cognitive flexibility is associated primarily with the prefrontal cortex (Barbey et al., 2013) and creative insight is related to increased activation of the anterior portion of the right superior temporal gyrus (Jung-Beeman et al., 2004). Despite surface similarities, therefore, creativity and cognitive flexibility may employ distinct processes.

Differences between creativity and cognitive flexibility may have been particularly exemplified by the tasks used in this project. The creativity tasks, for instance, required participants to solve problems and produce unique responses. In contrast, the categorization task required participants to learn a strategy and apply it to various stimuli. Kounios and Beeman (2009) have suggested that insight is fundamental for solving problems and understanding riddles or metaphors. Referring to work by Sternberg and Davidson (1995), they define insight as “a sudden comprehension ... that can result in a new interpretation of a situation” (Kounios & Beeman, 2009, p. 210); participants may have relied primarily on insight-based strategies to complete the creativity tasks in Study 1.

Insights occur unconsciously (Bowden & Jung-Beeman, 2003) and, as a result, may be distinguished from the types of deliberate, conscious strategies that participants likely implemented during the categorization task (Kounios & Beeman, 2009). Perhaps, therefore, noise is more beneficial for insight-driven problem solving than tasks which

involve the learning and conscious execution of complex strategies. The learning aspect of the categorization task may also have relied more on long term memory than the creativity tasks, for which performance of each item was independent of all other items. Noise has been shown to impair long term memory. Wais and Gazzaley (2011), for example, found that performance on a recall test was impaired when participants were exposed to restaurant noise during the learning phase of the task; the auditory stimulus used in this study contains unintelligible speech, and the sounds of cutlery, cups, and plates, and is, therefore, similar to restaurant noise. Consequently, the categorization task may have been prone to suffering from some of the negative effects of ambient noise on memory. Other measures of cognitive flexibility, which rely less on learning and long term memory, are available. The Cognitive Flexibility Scale (Martin & Rubin, 1995), for instance, is a self-report measure of cognitive flexibility as it occurs in the context of communication. Alternative measures, such as this, may be useful in future attempts to investigate the effects of ambient noise on cognitive flexibility.

Although noise was not found to enhance category learning, it should be noted that it did not impair category learning either; participants in both the medium and high volume conditions performed similarly to participants in the control condition, despite rating the noise as significantly distracting. In fact, the strategy analysis suggests that participants in the high volume condition settled on using the correct strategy earlier during the task than participants in the control condition. It was suggested in Chapter 2, Section 2.7.2.2., that the noise may have distracted participants and prevented them from fully concentrating on, and overthinking the creativity tasks at hand. A similar process may have occurred during the categorization task, such that participants were quicker to give up on incorrect strategies and switch to the correct rule-defined or associative-based strategy. Ambient noise, therefore, may have driven participants towards the use of the appropriate categorization strategy; however, it does not appear to have enhanced category learning, in general, or cognitive flexibility, specifically.

Chapter 4

4 General Discussion

This thesis sought to expand and extend the work of Mehta et al. (2012) by assessing the way in which ambient noise affects creativity and cognitive flexibility. Study 1 compared performance on three creativity tasks across three volume conditions. Implementing the same three volume conditions, Study 2 then examined performance on a category learning task designed to measure cognitive flexibility. Results from these studies suggest that creativity, but not cognitive flexibility, may be enhanced by ambient noise. Furthermore, the effects of noise on creativity seem to be moderated by individual differences in study and work preferences.

4.1 Study 1

Mehta et al. (2012) found a performance advantage for participants who completed several creativity tasks while being exposed to moderate volumes of ambient noise. They also found that enhanced creativity was directly related to increased levels of processing difficulty and cognitive abstraction. Study 1 provides support for the findings of Mehta et al. in that, under certain circumstances, participants in the medium volume condition performed better than those in the control and high volume conditions. Overall, however, results from Study 1 were not as consistent as those of Mehta et al., and an effect of noise on cognitive abstraction was not observed.

When all participants were considered simultaneously, Study 1 revealed a noise advantage for performance on only one aspect of the CRA task. Upon dividing participants into subsets based on their preferred study/work environments, effects of noise were also observed with respect to the insight problem task and AUT. This suggests that the relationship between ambient noise and creativity is moderated by individual differences. Perhaps, more consistent results would be obtained if other participant characteristics were taken into consideration.

For instance, Mehta et al. (2012) suggested that moderate noise may only be beneficial to creative performance for individuals who are naturally very creative. It is conceivable that the participant group in Study 1 was comprised of equal numbers of both modestly and highly creative individuals. If this was the case, any effect of noise on performance among the highly creative participants may have been nullified by a lack of effect among the participants of low creative abilities; future studies in this area may wish to include a creativity pre-screening task so that this possibility may be accounted for.

Amabile (1988) identified a number of other traits, including persistence, curiosity, energy, and intellectual honesty, which correlate with creative thought. She also suggests that self-motivation, as opposed to external motivation, is important for fostering creativity. At the time Study 1 was conducted, students in the Introductory Psychology class at the University of Western Ontario were required to either read six research articles or participate in six hours' worth of research studies over the course of the year. Failure to complete this requirement would result in the loss of 10 points from a student's final grade in the class. Study 1 participants were recruited from this group of students and were, thus, extrinsically motivated to complete the study. Individuals who participated in the studies of Mehta et al. (2012) were seemingly unaffected by the external motivation (in some studies, course credits and in others, \$10) they were provided. Study 1, however, was conducted during the last three months of the school year. During this time period, many participants remarked that they were hurriedly trying to complete their study requirements. Therefore, it seems likely that the detrimental effects of external motivation on creativity were particularly robust during Study 1. Performance may also have been impaired during the first few weeks of Study 1 because many participants were completing midterm exams at that time; given the amount of university-based research that relies on student participation, it would be interesting to investigate if and how participant performance fluctuates throughout the year.

4.2 Study 2

Although it was not conducted at the end of the year, external motivation may also have hindered performance on the category learning tasks during Study 2. As in Study 1, participants were awarded course credit for completing Study 2. If obtaining a course

credit was the primary reason for which participants completed Study 2, any beneficial effects of noise may have been dampened by a lack of motivation to perform well; this could explain the overall mediocre performance that was observed, and why some participants adopted a guessing method to complete the task.

Effects of noise on cognitive flexibility may also have been masked by the nature of the categorization task itself. To successfully learn the RD category set, participants were required to identify and apply a strategy over the course of 320 trials. With respect to the RD condition, strategy analysis suggests that more participants in the high volume condition used the optimal strategy throughout the task than participants in either of the other two conditions. This implies that noise may be beneficial during the process of strategy selection and application, perhaps by enhancing cognitive flexibility.

Presumably, however, this task also demanded working memory and long term memory, both of which have been shown to be impaired by noise (Chein & Fiez, 2010; Wais & Gazzaley, 2011). Any beneficial effect of noise on cognitive flexibility may, therefore, have been negated by negative effects of noise on the memory required to learn the RD category set. Competing influences of noise on cognitive flexibility and memory may explain why RD categorization was neither helped nor hindered by the presence of ambient noise; in effect, cognitive flexibility may have acted as a sort of protective factor that reduced the negative impact of impaired memory on RD learning. If this proposition is correct, noise-related enhancements of cognitive flexibility may be apparent through the use of non-learning-based measures of cognitive flexibility, such as The Cognitive Flexibility Scale (Martin & Rubin, 1995).

Based on COVIS (Ashby et al., 1998), the learning of II categories is believed to rely less on cognitive flexibility than RD learning. For this reason, II category performance was not expected to benefit from the presence of ambient noise. It is further suggested that II learning occurs through the gradual association between stimuli and responses, as opposed to through the implementation of rule-based strategies. The II strategy assessed in Chapter 3, Section 3.4.3, for instance, is a mathematically defined strategy, and not one which may have been readily identified and explicitly defined by participants. Due to the processes involved, it seems as though conscious memory may be less crucial for II

learning than for RD learning. This could explain why II categorization was not impaired by the negative effects of noise on memory.

4.3 Limitations and Future Directions

The lack of effects found in Study 2 may also be due to issues which were inherent in the experimental setup. Similarly, discrepancies between the results of Study 1 and Mehta et al. (2012) may have been caused by differences in the equipment that was used.

Specifically, a major limitation of both studies is that the volume of the conditions fluctuated throughout each testing session and over the course of each study. In fact, participants in the medium and high volume conditions generally rated the noise as equally distracting. This suggests that these conditions were perceptually similar, which limits the direct comparability between Study 1 and that of Mehta et al. An increase in the consistency of each condition could have been achieved if the studies were completed in sound attenuated rooms with artificially contrived noise. A dynamic noise stimulus, however, provides a closer approximation to the types of noise environments that exist in the real world. Consequently, these studies likely possess a greater degree of external validity than what would have been achieved had they taken place under more stringent conditions.

External validity is a valuable element of research to consider, particularly if the goal is to assess how a naturally occurring variable, such as noise, affects learning. In day-to-day life, it is rare that learning occurs in a carefully controlled environment; instead, it occurs in locations with diverse acoustical backgrounds, such as classrooms, workplaces, outdoors, and in the home. Study 2, however, is one of the first studies to assess the effects of noise on cognitive flexibility. Perhaps, therefore, a study involving simpler, more consistent sounds would have been a more suitable starting point for this line of research. An approach such as this would allow for a better understanding of how cognitive flexibility and sound interact at a fundamental level. This relationship may be further clarified by implementing a non-learning-based measure of cognitive flexibility; additional research is needed to examine if an effect of noise on basic cognitive flexibility exists.

It would also be interesting to investigate how cognitive flexibility is influenced by other types of noise. White noise, for instance, has been shown to improve attention for certain populations (Söderlund et al., 2010) and reverse the detrimental effects of sleep deprivation (Corcoran, 1962; Wilkinson, 1963). Furthermore, white noise may improve performance on cognitive tasks by acting as a mask for speech-based noise (Loewen & Suedfeld, 1992). Cognitive flexibility may similarly be improved simply by the presence of white noise; alternatively, it may benefit from the use of white noise as a mask for other types of noise. Research demonstrating such findings could be used to advocate for the use of white noise in classrooms or offices to enhance cognitive flexibility-driven problem solving and learning.

Comparing the effects of urban and nature-based sounds with respect to cognitive flexibility may also be a worthwhile endeavor. It has been suggested that nature sounds are related to positive shifts in mood states and physiological activity, both of which support a faster and more complete recovery from stress than what is observed during exposure to urban-based sounds (Ulrich, Simons, Losito, Fiorito, Miles, & Zelson, 1991). It seems likely that nature-based sounds would have a facilitatory effect on both cognitive flexibility and creativity, given that they may be enhanced by positive mood (Isen et al., 1987; Nadler et al., 2010); furthermore, a reduction in stress is something which both of these factors would likely benefit from.

In general though, future research in the area of noise and cognition should also consider the effects of individual differences. Mehta et al. (2012), for instance, proposed that the relationship between ambient noise and creativity is moderated by individual differences in baseline creativity; based on the results of Study 1, it seems likely that this relationship is also moderated by personal work preferences. In Chapter 2, Section 2.12, it was predicted that personal work preferences, and the resulting effect that they seem to have on creativity, were due to differences in dopamine levels. In particular, it was suggested that individuals who often listen to music while they work, subconsciously choose to do so to compensate for low brain levels of dopamine. If this conclusion was accurate, however, work preferences would likely have affected the relationship between noise and II category learning.

The associative learning involved in II categorization is believed to rely on dopamine-mediated reward signals (Maddox, Ashby, Ing, & Pickering, 2004). Consequently, if work preferences are related to levels of dopamine, noise should have enhanced II performance for those who enjoy listening to music while they work. This did not occur. Dopamine-associated stochastic resonance, therefore, does not appear to be a valid explanation as to why some individuals choose to work in noisy environments and benefit from doing so; this may be a question for future research to address.

4.4 Conclusion

Although this thesis did not reveal an effect of noise on cognitive flexibility, it outlines one of the first studies in this area of research. Category learning is only one type of task which employs cognitive flexibility. Consequently, the results of Study 2 should not be interpreted as meaning that cognitive flexibility is unaffected by noise, but that category learning, specifically, does not benefit from an effect of noise on cognitive flexibility. Additional research is needed to fully elucidate what, if any, effect that noise has on cognitive flexibility as it applies to other types of tasks like problem solving, for example.

Importantly, it should be noted that the presence of noise was not found to impair performance on any of the tasks considered in this project. In neither Study 1 nor 2 were participants in the control condition found to perform better than participants in either of the noise conditions. In fact, for those who typically listen to music while working, creative performance was found to be enhanced by the presence of noise. This finding has implications for both the classroom and the workplace. Students, for instance, may benefit from listening to music during creative classes such as art and drama.

Performance on tasks involving problem solving or creative writing may also be enhanced by music for students and professionals alike. Results from Study 1 suggest that a strategy such as this may only be helpful for certain individuals; as a result, headphones may be useful for allowing others to work in silence if they would prefer to do so.

In general though, even if an individual typically works in quiet environments, these studies suggest that their performance on category learning or creative thinking tasks is unlikely to be impaired by moderate amounts of noise. Noise is ubiquitous, and so, it is

advantageous for an individual to be able to adapt to the ambient environment and either work with noise or overcome it. Of course, for some types of work, such as that which requires intense concentration, quiet may be beneficial; for other types, however, there are always coffee shops.

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Appendices

Appendix A: The CRA (Bowden & Jung-Beeman, 2003) Items Used in Study 1

Item	Solution
Easy Difficulty	
basket/eight/snow	<i>ball</i>
sandwich/house/golf	<i>club</i>
preserve/ranger/tropical	<i>forest</i>
dew/comb/bee	<i>honey</i>
french/car/shoe	<i>horn</i>
cream/skate/water	<i>ice</i>
shine/beam/struck	<i>moon</i>
safety/cushion/point	<i>pin</i>
loser/throat/spot	<i>sore</i>
pike/coat/signal	<i>turn</i>
Medium Difficulty	
cross/rain/tie	<i>bow</i>
dust/cereal/fish	<i>bowl</i>
boot/summer/ground	<i>camp</i>
animal/back/rat	<i>pack</i>
officer/cash/larceny	<i>petty</i>
pie/luck/belly	<i>pot</i>
carpet/alert/ink	<i>red</i>
oil/bar/tuna	<i>salad</i>
change/circuit/cake	<i>short</i>
palm/shoe/house	<i>tree</i>
Hard Difficulty	
wise/work/tower	<i>clock</i>
grass/king/meat	<i>crab</i>
back/step/screen	<i>door</i>
shadow/chart/drop	<i>eye</i>
fight/control/machine	<i>gun</i>
mate/shoes/total	<i>running</i>
dive/light/rocket	<i>sky</i>
board/blade/back	<i>switch</i>
illness/bus/computer	<i>terminal</i>
cover/arm/wear	<i>under</i>

Appendix B: The Insight Problems (Dow & Mayer, 2004) Used in Study 1

Verbal Insight Problems:

Three women - Joan, Dana, and Sandy – have, among them, three children - Sam, Traci, and David. Sam likes to play with Dana's son. Sandy occasionally baby-sits for Joan's children. Who is Traci's mother? *Solution: Joan.*

There is a town in Northern Ontario where 5% of all the people living in the town have unlisted phone numbers. If you selected 100 names at random from the town's phone directory, on average, how many of these people selected would have unlisted phone numbers? *Solution: 0.*

Mathematical Insight Problems:

In the Smith family, there are 7 sisters and each sister has 1 brother. If you count Mr. Smith, how many males are there in the Smith family? *Solution: 2.*

Yesterday I went to the zoo and saw the giraffes and ostriches. Altogether they had 30 eyes and 44 legs. How many animals were there? *Solution: 15.*

Spatial Insight Problems:

Identify the next term in the series: 88, 64, 24, ? *Solution: 40.*

Three cards lie face down on a table, arranged in a row from left to right. We have the following information about them. a. The Jack is to the left of the Queen b. The Diamond is to the left of the Spade c. The King is to the right of the Heart d. The Spade is to the right of the King. Which card - by face and suit - occupies each position? *Solution: From left to right: Jack of Hearts, King of Diamonds, Queen of Spades.*

Appendix C: A Sample of the AUT (Guilford et al., 1960) Items Used in Study 1

1. **SHOE** (used as footwear)

a.

b.

c.

d.

e.

f.

2. **BUTTON** (used to fasten things)

a.

b.

c.

d.

e.

f.

Appendix D: The Follow-up Questionnaire Used in Studies 1 and 2

PANAS Questionnaire (Watson et al., 1988)

This scale consists of a number of words that describe different feelings and emotions. Read each item, and then mark the appropriate answer in the space next to that word. Indicate to what extent you have felt this way *right now, that is at the present moment*. Use the following scale to record your answers.

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely
		_____ interested		_____ irritable
		_____ distressed		_____ alert
		_____ excited		_____ ashamed
		_____ upset		_____ inspired
		_____ strong		_____ nervous
		_____ guilty		_____ determined
		_____ scared		_____ attentive
		_____ hostile		_____ jittery
		_____ enthusiastic		_____ active
		_____ proud		_____ afraid

Behavior Identification Form (Vallacher & Wegner, 1989)

Any behaviour can be described in many ways. For example, one person might describe a behaviour as "writing a paper," while another person might describe the same behaviour as "pushing keys on the keyboard." Yet another person might describe it as "expressing thoughts." This form focuses on your personal preferences for how a number of different behaviours should be described. Below you will find several behaviours listed. After each behaviour will be two different ways in which the behaviour might be identified.

For example:

1. Attending class
 - a. sitting in a chair
 - b. looking at a teacher

Your task is to choose the identification, a or b, that best describes the behaviour for you. Simply place a checkmark next to the option you prefer. Be sure to respond to every item. Please mark only one alternative for each pair. Remember, mark the description that you personally believe is more appropriate for each pair.

1. Making a list
 - a. Getting organized
 - b. Writing things down
2. Reading
 - a. Following lines of print
 - b. Gaining knowledge
3. Joining the Army
 - a. Helping the Nation's defense
 - b. Signing up
4. Washing clothes
 - a. Removing odours from clothes
 - b. Putting clothes into the machine

5. Picking an apple
 - a. Getting something to eat
 - b. Pulling an apple off a branch
6. Chopping down a tree
 - a. Wielding an axe
 - b. Getting firewood
7. Measuring a room for carpeting
 - a. Getting ready to remodel
 - b. Using a yard stick
8. Cleaning the house
 - a. Showing one's cleanliness
 - b. Vacuuming the floor
9. Painting a room
 - a. Applying brush strokes
 - b. Making the room look fresh
10. Paying the rent
 - a. Maintaining a place to live
 - b. Writing a cheque
11. Caring for houseplants
 - a. Watering plants
 - b. Making the room look nice
12. Locking a door
 - a. Putting a key in the lock
 - b. Securing the house

13. Voting

- a. Influencing the election
- b. Marking a ballot

14. Climbing a tree

- a. Getting a good view
- b. Holding on to branches

15. Filling out a personality test

- a. Answering questions
- b. Revealing what you're like

16. Toothbrushing

- a. Preventing tooth decay
- b. Moving a brush around in one's mouth

17. Taking a test

- a. Answering questions
- b. Showing one's knowledge

18. Greeting someone

- a. Saying hello
- b. Showing friendliness

19. Resisting temptation

- a. Saying "no"
- b. Showing moral courage

20. Eating

- a. Getting nutrition
- b. Chewing and swallowing

21. Growing a garden

- a. Planting seeds
- b. Getting fresh vegetables

22. Traveling by car

- a. Following a map
- b. Seeing countryside

23. Having a cavity filled

- a. Protecting your teeth
- b. Going to the dentist

24. Talking to a child

- a. Teaching a child something
- b. Using simple words

25. Pushing a doorbell

- a. Moving a finger
 - b. Seeing if someone's home
-

Follow-Up Questionnaire

Please circle your answer to the questions below.¹

1. How difficult did you find Task 1 (i.e. the three word task)?

1	2	3	4	5	6	7
Not at all difficult						Very difficult

2. How difficult did you find Task 2 (i.e. the word problem/riddle task)?

1	2	3	4	5	6	7
Not at all difficult						Very difficult

3. How difficult did you find Task 3 (i.e. the alternate uses task)?

1	2	3	4	5	6	7
Not at all difficult						Very difficult

4. How distracting did you find the background noise while you were completing the task?

1	2	3	4	5	6	7
Not at all distracting						Very distracting

Please write your answer to the following questions in the space provided.

3. Do you like to study/work with music playing in the background?

4. Which environments do you usually like to study/work in?

¹ In Study 2, items 2 and 3 were removed and item 1 was reworded as follows: "How difficult did you find the task?"

Appendix E: Ethics Approval for Studies 1 and 2



Research Ethics

Use of Human Participants - Initial Ethics Approval Notice

Principal Investigator: Dr. John Paul Minda
 File Number: 104617
 Review Level: Delegated
 Protocol Title: Background noise and cognition
 Department & Institution: Social Science Psychology, Western University
 Sponsor:
 Ethics Approval Date: December 12, 2013 Expiry Date: August 31, 2014

Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Other	Study 1 Task Sample	2013/10/31
Other	Method References	2013/10/31
Recruitment Items	Revised Study 2 SONA Recruitment (received Nov.20/13)	
Letter of Information & Consent	Revised Study 1 SONA LOI	2013/11/21
Recruitment Items	Revised Study 1 SONA Recruitment (received Nov.20/13)	
Letter of Information & Consent	Study 2, Paid LOI	2013/12/04
Recruitment Items	Study 2, Paid Recruitment Poster (Received Dec.4/13)	
Letter of Information & Consent	Study 1, Paid LOI	2013/12/04
Recruitment Items	Study 1, Paid Recruitment Poster (Received Dec.4/13)	
Letter of Information & Consent	Study 2, SONA LOI	2013/11/21

This is to notify you that The University of Western Ontario Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the applicable laws and regulations of Ontario has granted approval to the above named research study on the approval date noted above.

This approval shall remain valid until the expiry date noted above assuming timely and acceptable responses to the NMREB's periodic requests for surveillance and monitoring information.

Members of the NMREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussions related to, nor vote on, such studies when they are presented to the NMREB.

The Chair of the NMREB is Dr. Riley Hinson. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Curriculum Vitae

Name: Emily Nielsen

Education 2015 M.Sc. Cognitive Psychology
The University of Western Ontario, London, ON

2013 B.Sc. Honours Psychology: Research Specialist, Minor: Biology
Wilfrid Laurier University, Waterloo, ON

**Selected Honours
And Awards** Province of Ontario Graduate Scholarship (OGS)
The University of Western Ontario, 2014-2015

Social Sciences and Humanities Research Council (SSHRC)
Canada Graduate Scholarship – Master’s
The University of Western Ontario, 2013-2014

Dean’s Honour Roll
Wilfrid Laurier University, 2011, 2012, 2013

**Selected Work
Experience** Graduate Teaching Assistant
The University of Western Ontario
2013-2015

Teaching Assistant
Wilfrid Laurier University
2012-2013

Selected Presentations

Nielsen, E. G., & Minda, J. P. (May 2015). Creativity in the coffee shop: Ambient noise may improve performance on creativity tasks, but not on categorization tasks. *Poster presented at the 27th APS Annual Convention*, New York, NY, USA.

Nielsen, E. G., Rabi, R. R., & Minda, J. P. (March 2015). When the mind is exhausted, performance suffers on rule-based tasks. *Poster presented at the International Convention of Psychological Science (ICPS)*, Amsterdam, The Netherlands.

Nielsen, E. G., & Minda, J. P. (July 2014). The coffee shop effect: Investigating the relationship between ambient noise and cognitive functioning. *Poster presented at the 24th Annual Meeting of the Canadian Society for Brain, Behaviour, and Cognitive Science (CSBBCS)*, Toronto, ON, CAN.